TECHNICAL PUBLICATION 82-7

PERFORMANCE OF DISTRICT STRUCTURES DURING CRITICAL STORM EVENTS IN WEST MIAMI, AND PROPOSED ALTERNATIVES TO REDUCE FLOODING

By
N. Khanal

[redacted]

RESOURCE PLANNING DEPARTMENT
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WEST PALM BEACH, FLORIDA

SEPTEMBER 1982
(REVISED OCTOBER 1982)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART I. OPERATIONAL PERFORMANCE EVALUATION

INTRODUCTION

At the November 1981 South Florida Water Management District Governing Board Workshop, the City Engineer for West Miami made a presentation concerning the periodic flooding of that area during recent years (1979-81). The City Engineer felt that the recurring flooding problem in West Miami was due to the raising of the canal stages and, in turn, groundwater stages by the District. He requested that the District prepare a report evaluating the operation of the District's hydraulic structures (S-25B and G-97) in relation to rainfall and groundwater stages in the area. As a result of follow-up discussions, staff initiated a study to analyze the operation of the control structures during critical storm events, and to evaluate alternatives (both regional and local in nature) to alleviate the recurring flooding problem in West Miami.

Typical features of the West Miami area which bear on the flood hazard are moderately high rainfall and low land surface altitude and relief. In this area, flooding results from short periods of heavy rainfall, but the flooding does not necessarily coincide with the years of greatest precipitation. A factor that leads up to flood conditions is a heavy buildup of rainfall over several days, during which the drainage system has insufficient time to normalize groundwater levels. In the past, the area west of West Miami was undeveloped land and storm runoff from the east was discharged before the storm runoff from the west reached the primary canals. However, since the western area has now been highly urbanized, there is no time-lag to allow runoff from the eastern portion to drain first. Runoff water from the western amd eastern basins reaches the canals to be discharged simultaneously.

A related problem in this area is the need to maintain sufficiently high fresh water levels and canal flows to recharge wellfields which deliver more than 250 million gallons of water per day. These wellfields are susceptible to saltwater encroachment, especially during dry months.

It can be clearly seen, based on the above description, that the District must operate the control structures for both flood control and water supply purposes (multi-purpose uses). The objectives of the study will be to: (a) evaluate the operational strategy which has been applied to District control structures in the vicinity of West Miami during past storm events, and (b) evaluate an array of alternatives (both regional and local in nature) to help alleviate recurring flooding problems in West Miami.

DESCRIPTION OF STUDY AREA

The study area (West Miami) is located in east central Dade County. The project area, showing selected hydrologic features is presented in Figure 1. Figure 2 shows major drainage basins and topographic features of Dade County.

CLIMATE

The climate in the study area is sub-tropical. Rainfall averages approximately 60 inches per year, about 45 inches of which falls during the months of June through October. This five month period includes both the rainy season and the hurricane season. It is during this five month period that the area has a higher probability of being flooded; however, the area has flooded during dry months also.

SOILS, TOPOGRAPHY, AND LAND USE

The study area is located on the western edge of Coral Gables. A soil map of the area, prepared by the U. S. Department of Agriculture (10) shows the following soil groups in the area: (a) marl glades, (b) rocky pinelands, and (c) sandy prairies.

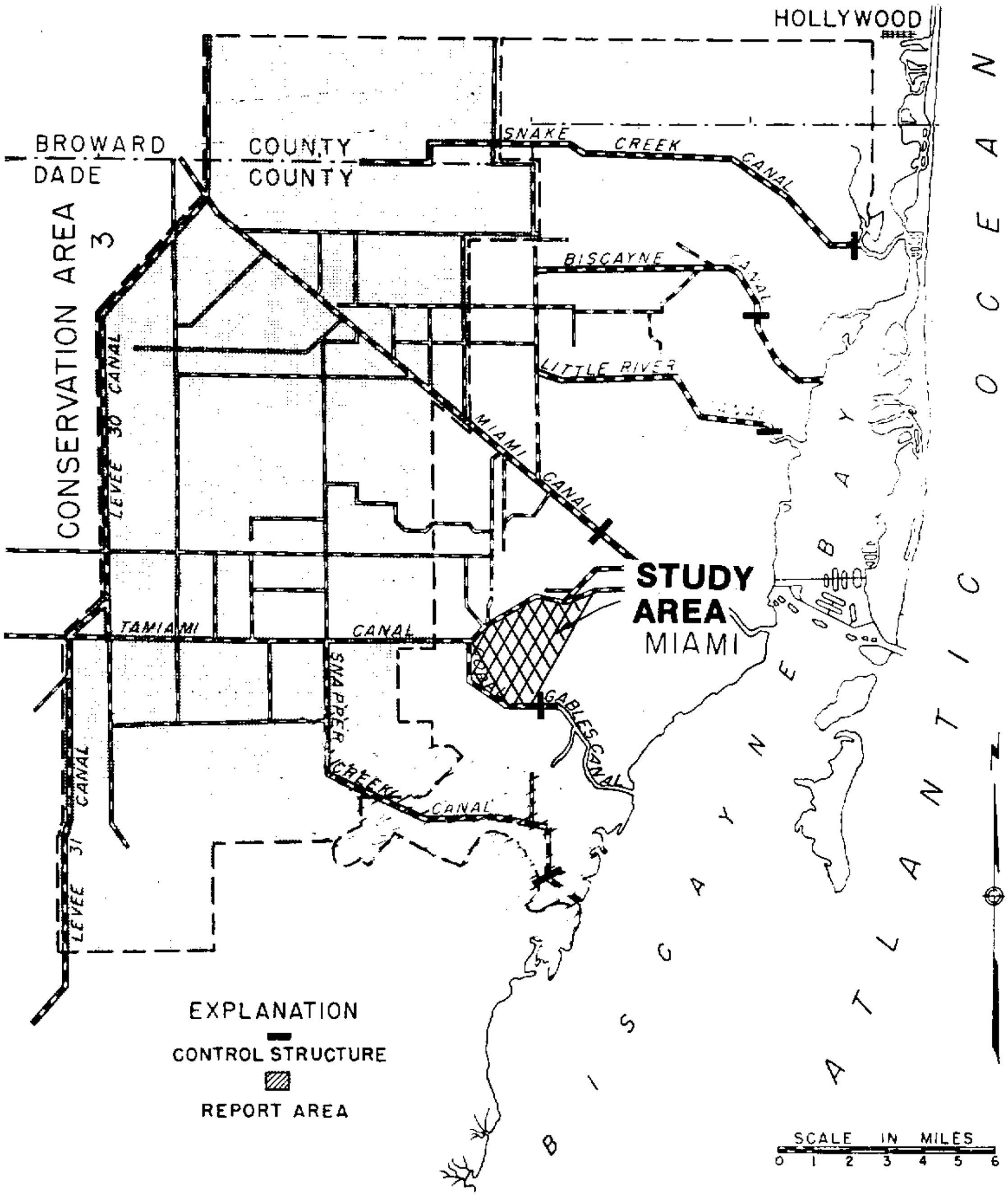


Figure 1 THE GREATER MIAMI AREA SHOWING SELECTED HYDROLOGIC FEATURES, DRAINAGE AREA BOUNDARIES, AND THE AREA INVESTIGATED

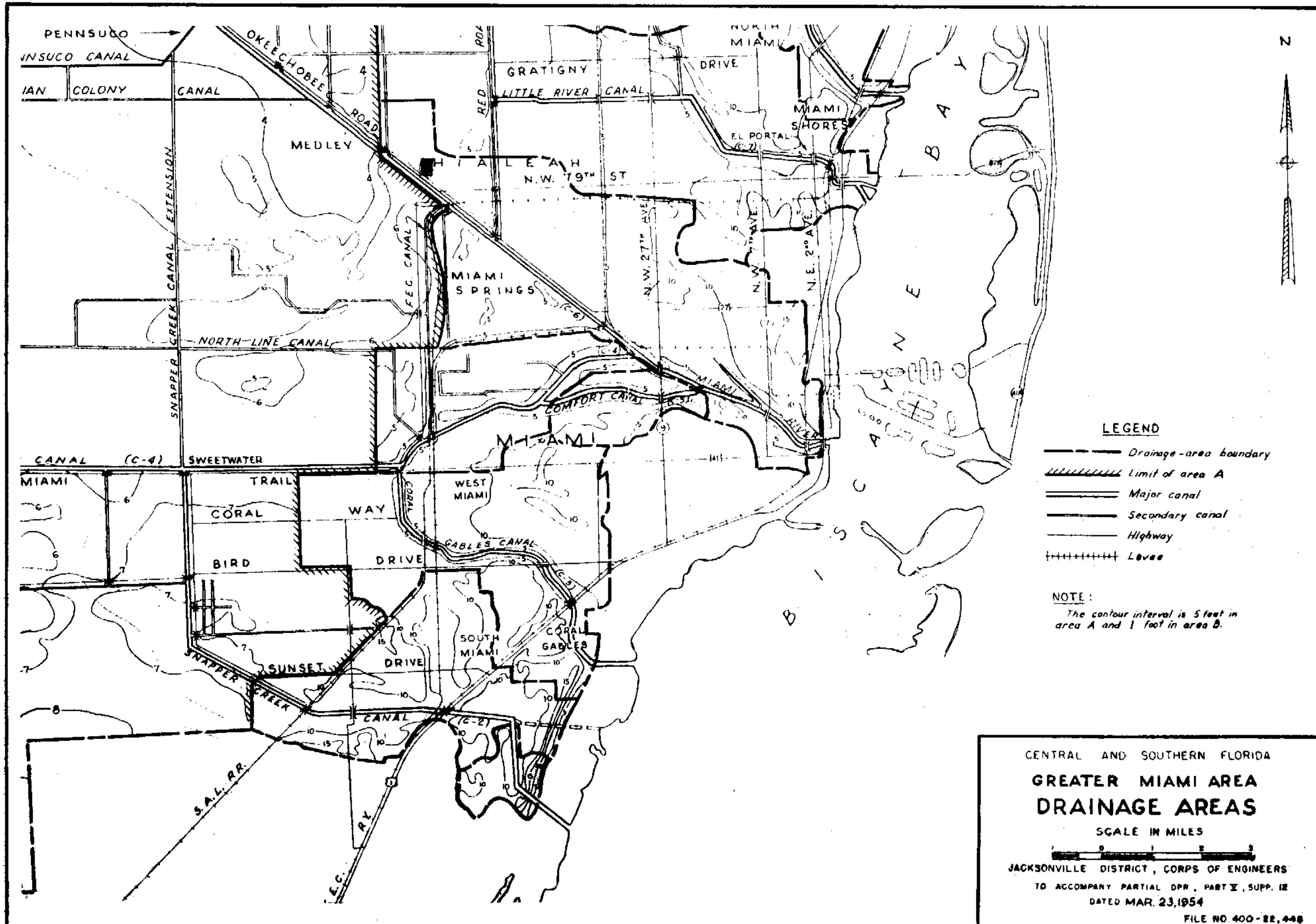

CENTRAL AND SOUTHERN FLORIDA
GREATER MIAMI AREA
DRAINAGE AREAS
SCALE IN MILES
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
TO ACCOMPANY PARTIAL DPR, PART V, SUPP. 12
DATED MAR. 23, 1954
FILE NO. 400-22,448
LEGEND
Drainage-area boundary
Limit of area A
Major canal
Secondary canal
Highway
Levee
NOTE:
The contour interval is 5 feet in area A and 1 foot in area B.
N
BISCAYNE BAY
PENNSUCO
MEDLEY
HIALEAH
MIAMI SPRINGS
MIAMI
WEST MIAMI
SOUTH MIAMI
CORAL GABLES
NORTH MIAMI
MIAMI SHORES
EL PORTAL
SWEETWATER
OKEECHOBEE ROAD
GRATIGNY DRIVE
LITTLE RIVER CANAL
N.W. 79TH ST
N.W. 27TH AVE
N.E. 2ND AVE
F.E.C. CANAL
NORTH LINE CANAL
SNAPPER CREEK CANAL EXTENSION
COMFORT CANAL
MIAMI RIVER
MIAMI CANAL (C-4)
TAMIAMI TRAIL
CORAL WAY
BIRD DRIVE
CORAL GABLES CANAL
SUNSET DRIVE
SNAPPER CREEK CANAL
(C-2)
(C-3)
(C-6)
S.A.L. RR.
F.E.C. RY

Figure 2

The surface mantle of marl glades soil consists of poorly drained marl that is 2-72 inches thick. This is underlain by oolitic limestone in the east and south, and by either Miami oolite or the Tamiami formation in the west. The rocky pineland forms a belt 4 to 10 miles wide that extends from Coconut Grove southwest to Florida City. Elevations average 9 feet above sea level, but range from 5 to 20 feet. The rocky pinelands are classified as being moderately drained.

Sandy prairies extend south and southwest from the Broward-Dade County line for a distance of about 20 miles. Originally, this land was poorly drained, but extensive drainage operations have lowered the water table of the area to some extent. The topographic elevation of the study area varies from a low of 5 feet NGVD along the western portion to a high of 10 feet NGVD (Figure 2).

Land use changes in the study area started as far back as 1937 with most of the changes being completed before 1955. At the present time, most of the land in this area is in impervious cover. Due to urbanization west of the study area, a large portion of the land surface has been covered by impervious surfaces which inhibit percolation and therefore results in greater peak flows and total volume of storm water. The existing surface water management system now has to handle greater peak flows than in the past.

HYDROGEOLOGY

The study area is underlain by the Biscayne aquifer. This aquifer is composed of highly permeable limestones, sandstones, and sand. Within this area the aquifer thicknesss varies from 85 feet in the western portion to about 120 feet along the coast. The Biscayne aquifer is the source of water for the Hialeah/Preston, Miami Springs, and Alexander Orr wellfields for metropolitan Miami. These wellfields all receive recharge water from the surface water canals in the area, especially during dry months when rainfall is low.

Water Supply Withdrawals

Presently, 272 million gallons of water is being withdrawn from this area. The District permits the Miami-Dade Water and Sewer Authority to withdraw up to 146 million gallons of water from the Hialeah/Preston and Miami Springs wellfields. Alexander Orr has a permitted withdrawal of 126 million gallons per day. It is estimated that as much as 378 million gallons of water will be needed by the year 2000, on a daily basis, to meet metropolitan Dade County's potable water requirements (9)). Sherwood and Leach (7) determined that as much as 50% of the water coming from the wellfields during dry months is canal water. In addition, approximately 53 cfs must be released to maintain a minimum canal stage of 2.8 ft. NGVD for saltwater intrusion. During the period of their study, the total withdrawal from the area's wellfields was approximately 130 mgd. Assuming the above recharge percentage (50%) to be still holding, as much as 210 cfs of water must be released to the canal to replenish the 272 mgd withdrawn from the wellfields, especially during dry months.

The Biscayne aquifer is subject to saltwater intrusion during critical low rainfall periods. Figures 3, 4, and 5 depict the extent of the saltwater encroachment before and after the District structures were put into operation.

Due to a constant threat of saltwater intrusion in the present wellfields, the Miami-Dade Water and Sewer Authority is developing two new wellfields; (1) the Northwest wellfield, and (2) the East Everglades wellfield. The Northwest wellfield, which is also known as the Three Square Mile wellfield, is located west of the present wellfield and is currently being tested. As much as 150 mgd may be withdrawn from this wellfield. The rest will be withdrawn from the East Everglades wellfield.

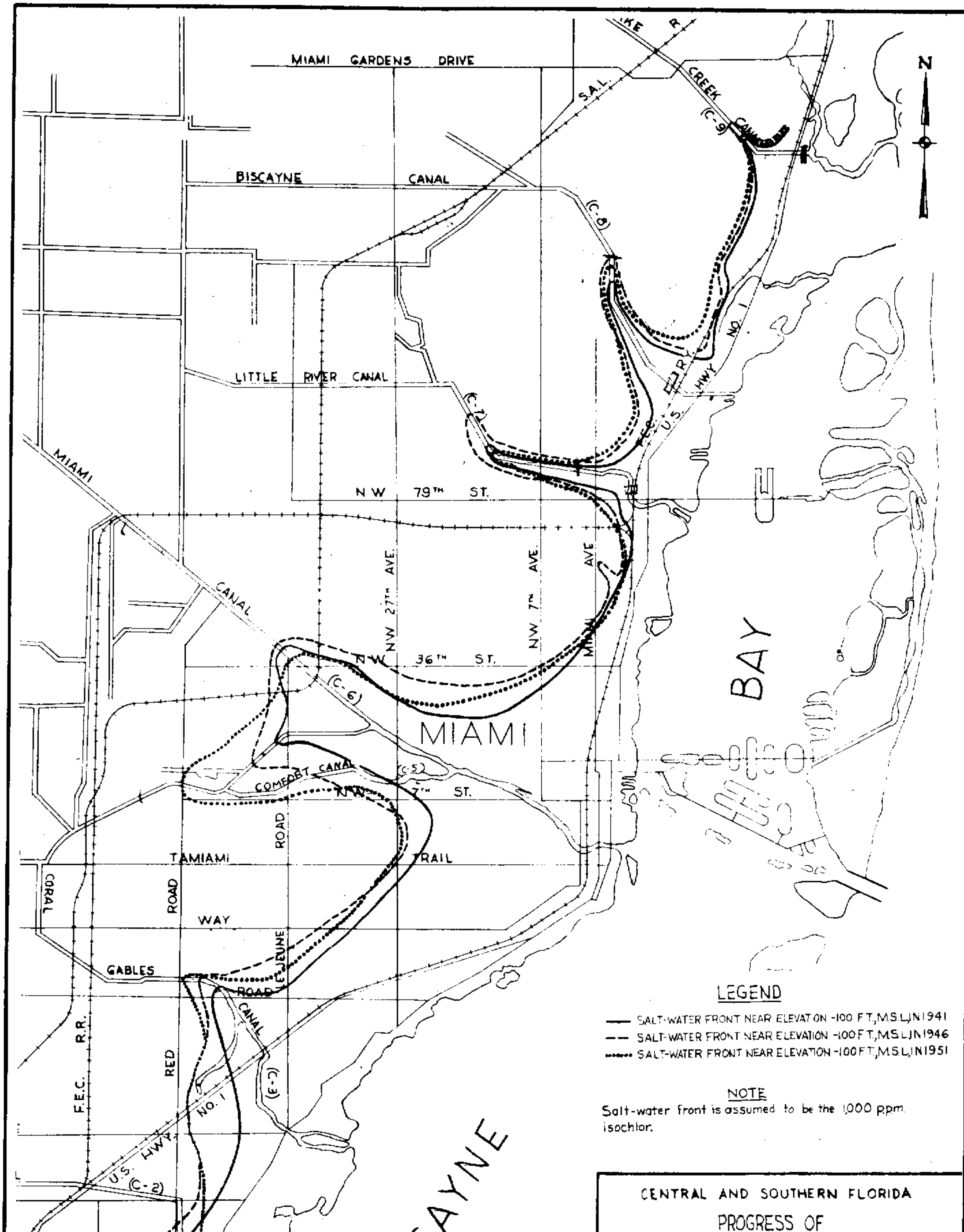
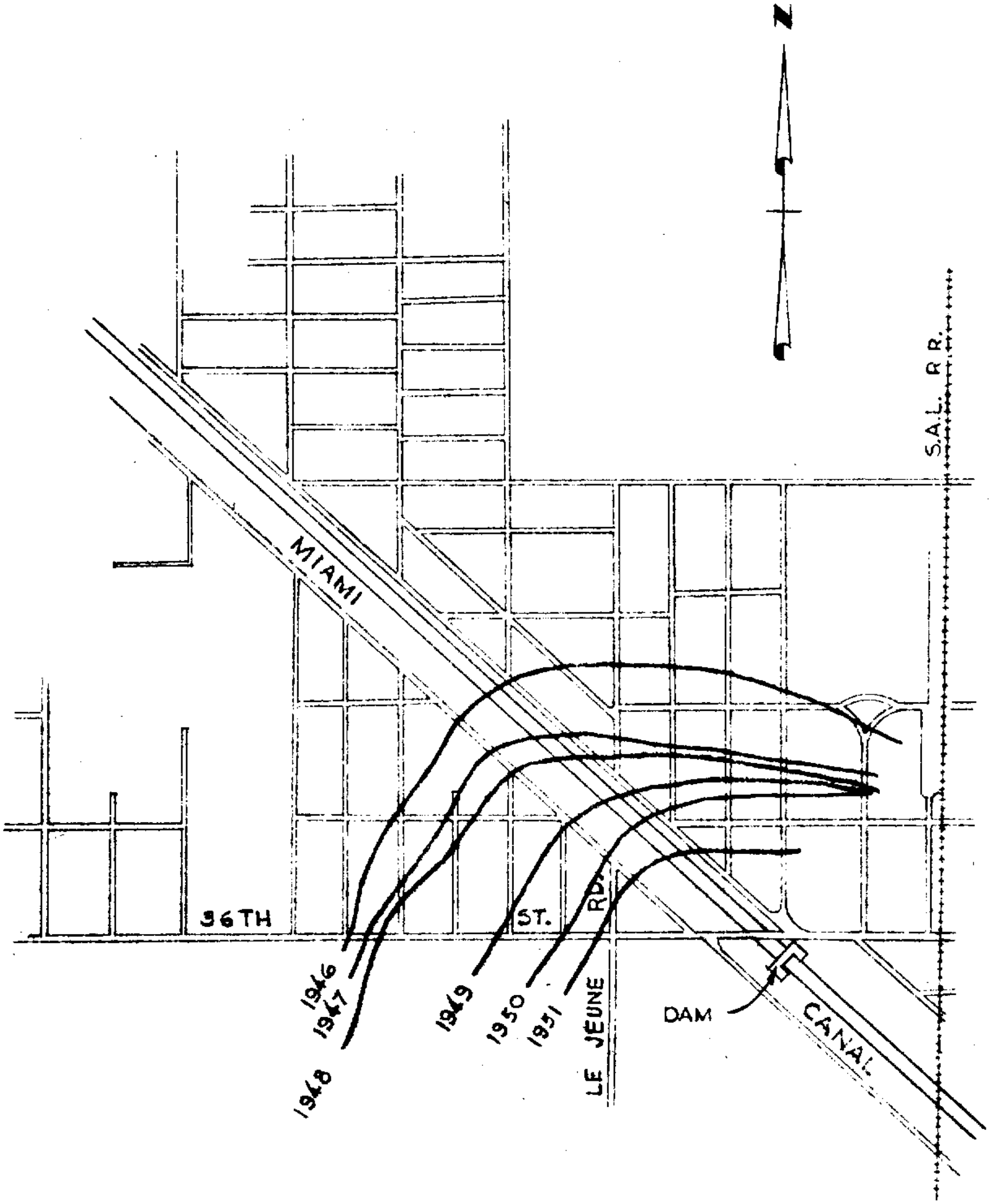

MIAMI GARDENS DRIVE
S.A.L.
CREEK
(C-9)
CANAL
N
BISCAYNE CANAL
(C-8)
LITTLE RIVER CANAL
(C-7)
F.E.C. R.R.
U.S. HWY. NO. 1
MIAMI
N W 79TH ST.
CANAL
NW 27TH AVE.
NW 7TH AVE.
MIAMI AVE.
BAY
NW 36TH ST.
(C-6)
MIAMI
COMFORT CANAL
(C-5)
NW 7TH ST.
ROAD
LE JEUNE
TAMIAMI TRAIL
CORAL WAY
ROAD
GABLES
ROAD
CANAL
(C-3)
RED
F.E.C. R.R.
U.S. HWY. NO. 1
(C-2)
BISCAYNE
LEGEND
SALT-WATER FRONT NEAR ELEVATION -100 FT., M.S.L., IN 1941
SALT-WATER FRONT NEAR ELEVATION -100 FT., M.S.L., IN 1946
SALT-WATER FRONT NEAR ELEVATION -100 FT., M.S.L., IN 1951
NOTE
Salt-water front is assumed to be the 1,000 ppm. isochlor.
CENTRAL AND SOUTHERN FLORIDA
PROGRESS OF
SALT-WATER ENCROACHMENT
SCALE IN MILES
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
TO ACCOMPANY PARTIAL DPR, PART V, SUPP. 13
DATED JULY 2, 1954
FILE NO. 400-22,682

Figure 3



NOTE

Salt front as shown for the various years is the 1,000 p.p.m. isochlor at elevation -100 ft., M.S.L.

CENTRAL AND SOUTHERN FLORIDA

SALT FRONT NEAR MIAMI CANAL DAM

SCALE IN FEET

JACKSONVILLE DISTRICT, CORPS OF ENGINEERS

TO ACCOMPANY PARTIAL D P R, PART V, SUPP 13

DATED JULY 2, 1954

FILE NO. 400-22,682

Figure 4

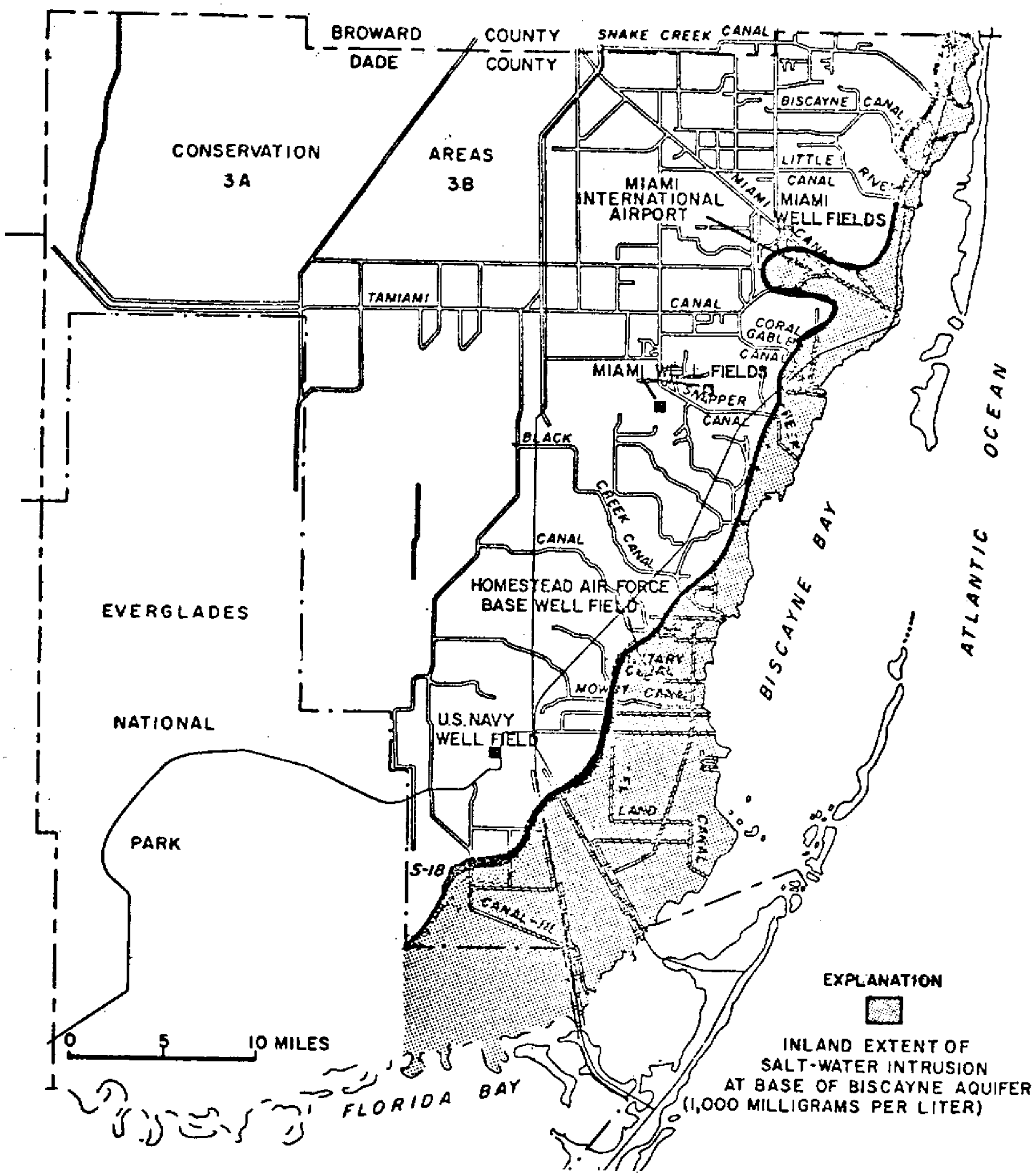


Figure 5 INLAND EXTENT OF SALTWATER INTRUSION, 1978-79

PRIMARY DRAINAGE FACILITIES

Primary drainage through the study area is through the Tamiami and Coral Gables Canals. Flow in these canals is regulated by the operation of District control structures (sheet pile barrier dam (G-97) on the Coral Gables Canal and a reinforced concrete gated spillway (S-25B) on the Tamiami Canal).

Structure Operations

District control structures are operated for multi-purpose uses. Kohout and Hartwell [4] have determined that a minimal canal stage of 2.7 ft. above msl is needed near the control structures to prevent saltwater encroachment in the Biscayne aquifer in Dade County.

District structure G-97 on Coral Gables Canal (C-3), together with S-25B on the Tamiami Canal (C-4), are operated to maintain a headwater elevation of 2.8 ft. above msl. G-97 is a sheet pile barrier and, during storm events, these sheet piles are difficult to operate (requires pulling sections out); therefore, required releases are normally made by S-25B. Presently, a dialogue has started between the Corps of Engineers and the District to replace G-97 with a more efficient control structure. The design discharge rate of G-97 is 640 cfs (40% SPF) and the design rate of S-25B is 2000 cfs (100% SPF). The design discharge rate of these two control structures should be able to maintain optimal groundwater stages in the West Miami area.

Operation of the gates at S-25B is automatically controlled. This structure is located in the City of Miami and is immediately downstream of the LeJuene Road crossing of the Tamiami Canal. The main gates at S-25B operate to maintain the upstream water surface elevation as follows:

1. When the headwater elevation rises to 3.0 ft., the gates will open at the rate of six inches per minute.

2. When the headwater elevation rises or falls to 2.9 ft., the gates will become stationary.

3. When the headwater elevation falls to 2.5 ft., the gates will close at the rate of six inches per minute.

Kohout and Hartwell (4) have compared the groundwater levels of the study area prior to inception of the Flood Control Project with those after the structures were placed in operation. They state that groundwater levels over most of the area prior to the Project were 9 to 10 feet above msl, or about 3 to 5 feet above land surface. After completion of the Project work, water levels in the study area ranged 5 to 8 feet above msl, or 2 to 4 feet lower than those before the completion of the Project.

SECONDARY DRAINAGE FACILITIES

Presently, there is no positive outfall from the study area to the regional drainage system. The internal drainage system of the area consists of french drains. Installation of the french drain system of storm water removal started some 30 years ago, but some improvements were made 4 or 5 years ago. According to the Land Use Comprehensive Plan for the area, the french drain method has proven to be a very cost effective means of drainage. French drains are supported by ballast rock and are used where the soils are not capable of supporting an open trench structure. Most french drain systems use 15 inch pipe. Larger pipes are necessary only in areas where excessive amounts of stormwater are expected.

Under present conditions, storm rainfall will first infiltrate vertically downward. Once it reaches the water table, it begins to move horizontally towards the primary drainage canals, depending on the hydraulic gradient (difference between the canal and groundwater stages). However, as groundwater flow is very slow, it takes several days for the groundwater flow to reach the primary canals and then recede.

The Comprehensive Land Use Plan for the City of Coral Gables (1) points out, under the heading of "drainage elements", that the "present natural system of stormwater removal cannot adequately handle the large amounts of rainfall which this area receives. The Plan recommends that additions to the system (including structures) must accompany or take precedence over the infiltration techniques for effective drainage."

Near the study area, the Florida Dept. of Transportation has a ditch alongside of Coral Way that is known as the Coral Way ditch. During the past storm event, the City of West Miami constructed a temporary connection between the ditch and one of the city's catch basins. Water was discharged to the ditch via a 4 inch diameter pipe at a rate of 600 gpm. After 24 hours of pumping, West Miami was able to lower the groundwater stage by as much as 2.0 feet(11).

HYDROLOGIC DATA BASE

PERIODS OF ANALYSIS

Daily records of rainfall, canal stages, structure operation, and groundwater stages were obtained from Dade County, the U.S.G.S., NOAA, and/or SFWMD records for the years 1968, 1979, 1980, 1981, and 1982. These years included periods when major flooding occurred in the West Miami study area.

Rainfall data were analyzed by first determining the monthly distribution of total annual rainfall. Daily rainfall values were next tabulated for rainfall periods that exceeded that average rainfall for that month. The amount of rain that fell during each of these events was then compared with rainfall events of one-day and two-day duration within 25-50-and 100-year return frequencies.

Daily stage and operation records for the Coral Gables and Tamiami Canals were analyzed for those periods when flooding occurred in the study area. Finally, daily groundwater data records or estimated levels were analyzed for periods when groundwater levels exceeded the minimum land surface elevation of 5.0 ft msl.

RAINFALL

Monthly distributions of total yearly rainfall for the years 1968, 1979, 1980, 1981, and 1982 from the Miami International Airport (MIA) and the District's Miami Field Station (MFS) are presented below in Table 1.

Table 1. Monthly Rainfall Values (Inches) - MIA and MFS

	1968		1979		1980		1981		1982	
	MIA	MFS	MIA	MFS	MIA	MFS	MIA	MFS	MIA	MFS
January	1.92	1.67	1.28	2.01	1.89	1.92	0.61	0.58	0.44	0.60
February	2.77	1.97	0.57	0.59	0.88	1.04	4.66	4.56	1.22	1.32
March	0.88	0.66	0.30	0.26	3.17	2.42	1.32	1.74	4.22	6.50
April	1.27	0.69	17.29	12.41	10.20	10.33	0.05	0.04	NA*	9.40
May	18.54	17.93	5.29	6.95	2.14	2.39	4.94	5.34	NA	6.70
June	22.36	15.93	4.06	3.48	3.02	4.28	5.49	6.09	NA	NA
July	6.15	6.57	5.06	8.36	9.40	9.26	2.78	4.78		
August	8.34	10.79	4.81	3.61	11.32	7.50	12.25	8.32		
September	11.11	6.44	13.36	11.84	5.60	8.58	14.79	12.88		
October	8.71	9.43	3.63	6.22	6.05	2.88	1.62	2.28		
November	1.21	1.17	1.62	1.96	3.47	4.36	2.14	2.17		
December	0.13	0.30	2.84	3.67	0.20	0.95	0.14	0.21		
Total	83.39	73.55	60.11	61.36	57.34	55.91	50.79	58.99		

*Not Available

The foregoing table depicts the monthly and annual rainfall variations between the two stations, which are only a few miles apart. Additionally, as the intent of this report was to analyze the structure operations during critical storm periods, further breakdown of the monthly values to daily values was necessary. The daily values for each month of the year, whenever the monthly values exceeded the average monthly rainfall (Table 2), is presented in Table 3.

Table 2. Average Monthly Rainfall Values - Miami International Airport

Month	Rainfall (Inches)
January	2.15
February	1.95
March	2.07
April	3.60
May	6.12
June	9.00
July	6.91
August	6.72
September	8.74
October	8.18
November	2.72
December	1.64
Total	59.80

Table 3. Daily Rainfall Values When the Monthly Total Exceeded the Average Year of 1968

Date	Rainfall (Inches) MIA	MFS
May 19	4.42	0.00
20	1.03	1.94
21	0.12	0.38
22	0.21	0.19
23	0.25	1.81
24	0.46	0.26
25	0.30	0.00
26	2.22	0.00
27	0.03	3.29
28	0.20	0.00
29	1.20	0.32
30	0.21	0.00
31	0.20	1.72
	10.85	9.91

Table 3 (Continued)

Year of 1968

Date		Rainfall (Inches) MIA	MFS
June	1	0.39	0.00
	2	1.11	0.00
	3	2.55	2.76
	4	0.28	1.92
	5	0.34	0.15
	6	0.69	0.00
	7	0.50	0.00
	8	3.42	0.00
	9	0.33	0.00
	10	1.43	2.37
	11	0.02	1.41
	12	0.01	1.89
	13	0.04	0.12
	14	0.41	0.00
	15	0.11	0.00
	16	1.46	1.12
	17	0.42	0.86
	18	2.46	0.97
	19	0.00	0.00
		15.97	13.57
September	24	0.34	0.25
	25	1.70	0.00
	26	2.49	0.88
	27	0.35	2.04
	28	0.04	0.00
	29	0.01	0.00
	30	1.72	0.49
		6.65	3.66

Year of 1979

April	24	1.39	0.00
	25	14.85	11.64
	26	0.00	0.73
	27	0.00	0.00
		16.24	12.37
September	24	0.34	0.25
	25	1.70	0.00
	26	2.49	0.88
	27	0.35	2.04
	28	0.04	0.00
	29	0.01	0.00
	30	1.72	0.49
		6.65	3.66

Table 3 (Continued)

Year of 1980

Date		Rainfall (Inches) MIA	MFS
April	5	0.45	0.00
	6	0.16	0.00
	7	4.02	1.53
	8	0.01	3.16
	9	0.78	0.00
	10	0.09	2.28
		5.51	6.97
July	13	0.15	0.00
	14	0.98	0.34
	15	1.02	0.98
	16	0.83	0.31
	17	1.44	1.31
	18	0.25	1.09
	19	1.45	0.00
	20	0.30	0.00
	21	0.11	2.11
	22	0.27	0.48
	23	0.32	0.22
		7.12	6.84

Year of 1981

		MIA	MFS
August	16	1.28	0.00
	17	2.50	2.70
	18	2.75	7.80
	19	0.19	1.45
	20	1.31	0.28
	21	0.10	0.33
		8.13	12.56
September	3	0.04	0.00
	4	0.01	0.03
	5	0.04	0.00
	6	0.04	0.00
	7	2.33	0.00
	8	0.03	2.58
	9	2.04	0.05
	10	0.17	2.05
	11	0.11	0.45
	12	0.02	0.00
	13	0.05	0.00
	14	0.01	0.56
	15	0.06	0.82
	16	0.99	0.05
	17	0.19	1.25

Table 3 (Continued)

Year of 1981	Rainfall (Inches) MIA	MFS	
September 18	0.01	0.32	
19	0.00	0.00	
20	1.01	0.00	
21	0.01	0.32	
22	1.20	0.07	
23	0.01	0.00	
24	0.00	0.00	
25	4.36	0.00	
26	0.79	0.00	
27	2.65	0.00	
28	0.00	4.05	
29	0.00	0.08	
	16.17	12.68	
Year of 1982			
March 24	0.00	0.73	
25	1.01	0.00	
26	0.08	1.10	
	1.09	1.83	
April 23	0.05	0.00	
24	7.25	0.00	
25	0.78	0.00	
26	0.91	8.72	(Cumulative for 3 days)
	9.19	8.72	

The above table depicts that even the daily rainfall amounts measured at two nearby stations are different. Presently, West Miami does not have any raingage stations. The District has agreed to provide the city with a raingage station so that the exact quantity of rain that falls in the city can be measured in the future. However, rainfall amounts measured at these two stations were used in the analysis.

A report was recently prepared by the District which estimated the return frequencies for rainfall events of maximum 1 and 2 day durations [8]. The Log-Pearson Type III Distribution was applied to estimate the rainfall and durations for rainfall events of 25, 50, and 100 year return frequencies. In Table 4, rainfall events having return frequencies of 25, 50, and 100 years for 1 and 2 day durations are presented for the study area.

Table 4. Rainfall (Inches) in Events of One and Two Day Duration that Occur With 25, 50, and 100 Year Return Frequencies

Duration (Days)	Return Frequency	Rainfall (Inches)
1	1 Year in 25 Years	10
1	1 Year in 50 Years	12
1	1 Year in 100 Years	14
2	1 Year in 25 Years	12
2	1 Year in 50 Years	14
2	1 Year in 100 Years	16

A comparison of Tables 3 and 4 shows the study area received in excess of 10 inches of rainfall on only one particular day. This event occurred on April 25, 1979, when the study area received 14.85 inches of rain (MIA) on a single day. The return frequency of this rainfall is greater than 1 in 100 years. This event also exceeded the rainfall of a 2 day 1-in-50 year event.

However, as reported by the city engineer, this area has experienced three major flooding events during the past years. Therefore, the above comparison simply shows that past flooding in the study area was not caused by isolated major events. Flooding was probably due to a combination of antecedent hydrologic conditions (rainfall, groundwater, and canal stage) in the area.

CANAL STAGES UPSTREAM OF STRUCTURES DURING PAST STORM EVENTS

It was stated earlier in the text that the primary canals in the study area are the Tamiami and Coral Gables Canals. Presently, the upstream stages of the Tamiami Canal are controlled by S-25B. This is a new structure which was made operational after the 1970's. Before this, during the storm event of 1968, a structure existed on the Tamiami Canal near the FEC Railroad. Presented in Tables 5, 6, and 7, are the upstream stage records from the Tamiami Canal near the FEC RR, G-2 Coral Gables Canal, and S-25B.

A spot reading of the Coral Gables Canal during the April 1982 storm event was obtained from DERM. These readings are presented in Table 8.

Form No. 155

OPERATION LOG

C.&S.F.F.C.D.

MONTH ____________ STRUCTURE TAMIAMI CANAL e F.E.C. R.R. YEAR 1968

DATE & TIME	STAGE Upper & Lower	Height of Gate Opening in Bay Number 1	2	3	4	REMARKS
1968 Jan.		(a) (b)				No change during month Closed full
Feb.						No change during month Closed full
March						No change during month Closed full
April						No change during month - closed full
5-14-68 11:00am	3.30 / 1.20					6 half needles out
5-16-68 3:40pm	2.88 / 1.40					3 half needles out
5-20-68 10:00am	3.40 / 1.40					3 half and 2 full needles out
5-21-68 11:02am	3.28 / 1.54					3 half and 4 full needles out
5-26-68 4:00pm	3.08 / 1.95					6 half and 4 full needles out
5-29-68 8:16am	2.74 / 1.82					all needles out
June						all needles out No change during month
July						all needles out No change during month
8-2-68 4:20pm	2.82 / 1.54					6 half open
9-2-68 3:00pm	2.68 / 1.10					2 half open
9-25-68 1:30pm	3.05 / 2.38					6 half & 2 full open
9-26-68 3:45pm	3.06 / 2.68					open full
10-7-68 9:30am	2.00 / 1.70					Open full to 6 half out
10-16-68 2:25pm	2.42 / 1.46					All needles out

(a) BEFORE CHANGE
(b) AFTER CHANGE
STAGE READINGS ARE BEFORE CHANGE

TABLE 5. STRUCTURE AT TAMIAMI CANAL AND FEC RR

SHEET 4

FCD
FORM 555
1967

C.&S.F.F.C.D.

OPERATION LOG

MONTH ______

STRUCTURE TAMIAMI CANAL @ F.E.C.R.R. YEAR 1968 / 1969

DATE & TIME	STAGE Upper & Lower	Height of Gate Opening in Bay Number 1	2	3	4	REMARKS
10-30-68	2.48	(a)				
10:30am	1.42	(b)				6 half needles out
Nov.						No change during month
12-2-68	2.54					5 half needles in - 1 out
10:30am	1.42					
12-31-68	2.75					
10:18am	0.76					all closed
1-11-69	3.20	All closed				-
9:00pm	0.90	6 half needles out				
1-17-69	2.64	6 half needles out				
2:30pm	1.26	All in				
1-20-69	3.34	All in				
10:12am	0.76	5 half needles out				
1-30-69	2.52	5 half needles out				
3:15pm	0.90	All in				
2-14-69	2.86	All in - closed full				
9:15AM	1.30	2 half needles out				
2-15-69	3.60	2 half needles out				
6:00PM	0.96	5 half - 1 full out				
2-24-69	2.80	5 half - 1 full out				
11:00AM	1.06	all in - closed full				
March						No change during month
April						No change during month
5-5-69	3.32	all in				
3:30pm	1.42	3 halves out				
5-22-69	3.00	3 halves out				
4:00pm	0.96	closed				
6-6-69	3.00	all closed				
9:00am	0.90	6 half 1 full out				
6-6-69	4.16	6 half 1 full out				
4:00pm	2.04	all needles out				
6-26-69	2.68	all needles out				
9:00am	2.20	5 half out				

(a) BEFORE CHANGE
(b) AFTER CHANGE
STAGE READINGS ARE BEFORE CHANGE

TABLE 5 (Continued)

SHEET 5

V71 1 9 6 8 G-2 CORAL GABLES CANAL 13-54-40

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
1		2.90	2.92	2.60	2.40		2.35	2.10		2.65	
2	2.95	2.89		2.60			2.37	2.40		2.22	
3	2.93			2.64	2.35	3.42	2.24		2.72	1.80	
4	2.94		2.84	2.59		3.00			2.70	2.13	2.26
5	2.94	3.04	2.64	2.58		2.50		2.97	2.73		
6		3.05			2.50	2.75		2.89	2.73		2.30
7		3.06	2.88		2.64	2.74		2.84		1.56	2.35
8	2.86	3.01	2.86	2.50	3.00		2.20	2.85		2.37	
9	2.87	2.99		2.48	3.00		2.50	2.82	2.58	2.24	2.22
10	2.90			2.50	3.10	3.26	2.35		2.76	2.20	1.94
11	3.00		2.85	2.48	3.55	3.18	2.10		2.65	2.33	
12	2.99	2.95	2.80	2.48		3.48	2.60	3.35	2.86		2.69
13		2.96	2.90		3.50	2.50		2.92	3.20		
14			2.84		2.40	2.30		2.74		2.53	2.79
15	2.95	2.90	2.80	2.48	3.20		2.24	2.58		2.47	
16	2.94	2.87		2.48	3.17		2.27	2.45	2.70	2.58	
17	2.90			2.43	3.18	2.30	2.53		2.57	2.53	
18	2.93		2.86	2.42		2.50	2.68		2.55		2.85
19	3.08	2.95	2.82	2.47	3.77	2.50	2.74	2.35	2.89		
20		2.95	2.82		2.22	2.67		2.60	2.88	2.15	
21		2.92	2.77		3.05	2.18		2.60		1.90	2.85
22	3.09		2.77	2.42	3.05		2.48	2.75		1.95	
23	3.04	2.92		2.40	3.05		2.40	2.75	2.90		
24	3.07			2.37	2.95	1.75	2.25		2.95	2.60	
25	3.04		2.70	2.40		2.32	2.40		2.97		2.80
26	3.00	3.04	2.72	2.52	3.27	2.25	2.52	1.75	2.35		
27		2.98	2.73		3.10	2.78		2.80	2.27		
28		2.93	2.72		2.78	2.50		2.75		2.20	
29	2.91	2.90	2.70	2.41	2.73		2.21	2.93		2.25	
30	2.90			2.39		2.82		2.95	1.83		
31	2.90				2.80		2.17			2.27	
MEAN	2.96	2.95	2.80	2.48	2.94	2.65	2.38	2.68	2.68	2.24	2.50
						HIGH		3.77			

TABLE 6. G-2, CORAL GABLES CANAL

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR. FACTORS

Hi	Low	Date

STAGE RECORD

☐ Min-Max Gage
☐ Min-Max MK II
☐ Continuous Recorder

Year 1979 Gage Designation G-2

	January			February			March			April		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1							278	270	265			
2							276	269	265	240	234	229
3	3.00	285	277							239	234	223
4	294	288	279							240	230	225
5	295	289	283	353	267	249	276	268	261			
6				273	266	262	274	269	262	242	234	230
7				272	266	261	279	273	265			
8	296	282	277	273	266	261	277	272	267			
9	289	284	272	273	268	261	278	270	265			
10	289	281	277				277	267	263	240	233	224
11										232	220	224
12	286	280	273	274	265	258	277	267	262	235	227	222
13				275	269	257	272	269	260	234	227	222
14				277	270	257	269	263	257			
15				277	268	256	268	263	254			
16	292	284	272	274	268	260	268	260	255			
17	290	276	272							233	296	211
18	281	270	265							231	224	218
19	287	281	263				269	254	180	229	221	211
20				274	267	252				227	219	214
21				273	266	261	260	254	240			
22	293	277	267	279	273	261	259	251	247			
23	284	278	272	281	274	266	251			224	214	209
24	284	277	270				248			220	213	207
25	285	278	273				244					
26	284	275	271	284	276	267	255	245	242	497	414	210
27				282	274	270	253	245	241	420	384	377
28				280	272	269	250	242	236			
29							257	238	234			
30							242	235	231			
31												

TABLE 7. G-2, CORAL GABLES CANAL STAGE RECORD

Sea Level Datum of 1929, S.L.D.

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR FACTORS

Hi	Low	Date

STAGE RECORD

☐ Min-Max Gage
☐ Min-Max MK II
☐ Continuous Recorder

Year 1979 Gage Designation G-2

	May			June			July			August		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1	387	353	337	309	299	291						
2	363	345	340				297	289	283	310	299	294
3	363	343	331				295	288	277	304	294	281
4	350	332	329	305	299	294	2					
5	324	300	300	305	294	290	287	276	271			
6				317	294	287	282	[illegible]	[illegible]			
7				301	291	287				313	301	257
8						303						
9												
10							307	299	267			
11	325	299	299				307	294	284			
12				304	282	277	330	309	284			
13				303	281	277	319	[illegible]	302			
14				292	275	272	317	302	297			
15	317	309	292	289	283	270	308	299	294	311	292	283
16	319	309	304									
17	328	311	307							302	294	289
18	327	307	303	302	293	275	308	299	291			
19				314	307	288						
20				314	296	292						
21	317	298	293	303	299	290						
22	306	292	287	301	291	288						
23	298	287	282				342	318	290			
24	296	290	278				324	319	305	319	306	219
25	295	290	277									
26							324	309	304			
27				298	290	283	317	309	304			
28				[illegible]	[illegible]	[illegible]				293	285	279
29	330	317	278	[illegible]	289	288				292	284	277
30	323	310	303									
31	317	304	300							292	284	277

TABLE 7 (Continued)

Sea Level Datum of 1929, S.L.D.

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR. FACTORS

Hi.	Low	Date

STAGE RECORD

☐ Min-Max Gage
☐ Min-Max MK II
☐ Continuous Recorder

Year 1979 Gage Designation G-2

	September			October			November			December		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1				380	364	358	295	294	285			
2				371	357	352	303	294	285			
3				364	349	349				291	264	258
4	308	301	293	357	344	339				290	263	259
5	3.00	2.99	299	352	341	335				289	282	260
6	302	299	299							292	276	259
7	312	304	294				304	294	284	307	299	272
8							306	294	287			
9				349	320	315	305	294	289			
10	312	301	292	327	314	311				332	301	294
11	314	303	295	322	310	305				327	299	295
12	321	311	297	324	309	305				311	284	279
13	321	311	297				305	295	288	312	281	280
14							327	314	290			
15							321	304	298			
16				347	39	300	308	302	295			
17												
18				347	331	325				284	269	259
19		309		338	325	318				287	280	269
20	317	303	297							287	274	261
21										283	277	267
22												
23				334	309	302						
24				319	304	300						
25	334	310	292	315	307	249						
26	332	324	304				290	281	266			
27	332	326	306							267	261	262
28	296	[illegible]	297				299	281	272			
29				305	294	286	291	284	277			
30	316	299	293	303	297	287	292	280	279			
31				303	294	289				280	[illegible]	251

TABLE 7 (Continued)

Sea Level Datum of 1929, S.L.D.

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR. FACTORS

Hi	Low	Date

STAGE RECORD

- [ ] Min-Max Gage
- [ ] Min-Max MK II
- [ ] Continuous Recorder

Year 1980 Gage Designation G-2

	January			February			March			April		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1				307	279	275				279	[illegible]	265
2	279	266	257							322	294	265
3	272	264	255							300	289	282
4				287	268	262	331	303	279			
5				277	268	262	340	299	295			
6				273	276	260	303	282	[illegible]			
7							297	284	277	297	277	269
8	291	280	267	277	274	257				307	299	270
9	292	287	279							307	294	289
10	292	286	278							307	299	288
11	292	280	273	287	274	267	295	274	269	306	297	281
12				279	272	267	285	279	267			
13				278	264	260	285	279	260			
14	288	281	273	279	274	259	287	281	262			
15	288	281	277	287	281	268						
16	289	280	278							303	287	279
17	289	281	268				282	274	257	307	289	287
18	290	282	273				297	272	266	292	279	272
19				292	280	269	292	269	267			
20							278	269	264			
21	289	271	267				272	271	264	320	291	271
22	287	265	266							319	290	271
23	286	267	262							300	279	275
24	286	260	255				279	275	265	294	291	272
25	276	270	254	292	281	275	277	271	266	290	[illegible]	282
26				288	268	263	288	274	265			
27				279	273	262	[illegible]	[illegible]	265	297	284	270
28	315	300	263	279	274	267	279	274	266			
29				291	284	269						
30										297	279	271
31							279	271	261			

TABLE 7 (Continued)

Sea Level Datum of 1929, S.L.D.

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR FACTORS

Hi	Low	Date

STAGE RECORD

☐ Min-Max Gage
☐ Min-Max MK II
☐ Continuous Recorder

Year 80 Gage Designation G-2

	May			June			July			August		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1	291	279	274							319	311	294
2	287	279	274	295	279	272	315	295	285			
3				294	278	271	317	297	287			
4				295	279	272						
5				287	271	267						
6	290	284	275	277	266	260				309	299	288
7	289	282	277				311	291	289	306	294	290
8	287	281	274				314	299	294			
9	288	282	275	271	264	248	313	284	280			
10				269	269	251	312	293	276			
11				279	274	259	309	288	284			
12	304	292	276	287	280	267						
13				282	276	261						
14							303	287	275			
15	297	284	274				302	284	271			
16	296	283	271	292	262	257	300	288	272			
17				291	261	257	320	306	279			
18							334	327	301			
19	291	281	273	[illegible]	[illegible]	[illegible]	X					
20	290	279	273	295	287	257	Y					
21							338	321	315			
22	290	284	264				324	316	311			
23				298	293	283	320	317	312			
24				297	292	282	321	319	312			
25				299	292	285	321	315	311			
26				299	289	285				342	319	287
27				302	291	287				343	318	287
28	298	287	279				322	302	299	342	314	287
29	[illegible]	287	279							342	316	287
30	299	289	279	314	307	284	[illegible]	[illegible]	[illegible]			
31							317	309	292			

TABLE 7 (Continued)

Sea Level Datum of 1929, S.L.D.

'TROPOLITAN DADE COUNTY
.ATER CONTROL DIVISION

CORR. FACTORS

Hi.	Low	Date

STAGE RECORD

- ☐ Min-Max Gage
- ☐ Min-Max MK II
- ☐ Continuous Recorder

Year '80 Gage Designation ____________

	September			October			November			December		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1										310	[illegible]	292
2										305	[illegible]	292
3	355	339	298				312	304	292			
4	357	340	298				[illegible]	304	297			
5	355	347	335				304	303	297	308	299	295
6				305	297	287	304	302	291			
7				311	299	289	309	301	293			
8	354	336	331	301	289	284				308	303	294
9	352	334	331	322	313	299				309	301	295
10	341	333	325	318	309	307				307	297	292
11	342	334	325							306	296	291
12	339	327	317				310	300	287	305	291	287
							309	299	286			
14				317	299	294	310	299	288			
15	344	339	321	323	318	292				298	287	282
16	350	341	322	324	319	292				293	285	282
17	357	339	329	325	317	312	322	312	292	297	290	282
18	357	341	326							298	291	283
19	345	337	332							297	291	288
20				324	308	295	319	305	299			
21				307	297	292	318	308	299	297	290	285
22	341	321	317	300	295	287	310	303	295	297	292	276
23	341	321	311	301	293	288						
24	341	320	311	300	290	289	310	303	295			
25	327	3.11	3.07				309	302	29[illegible]			
26	312	300	297									
27				304	299	291						
28												
29										297	289	281
[illegible]				304	298	292				297	287	282
31				304	298	292						

TABLE 7 (Continued)

Sea Level Datum of 1929, S.L.D.

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR. FACTORS

Hi	Low	Date

STAGE RECORD

☐ Min-Max Gage
☐ Min-Max MK II
☐ Continuous Recorder

Year 81 Gage Designation G-2

	September			October			November			December		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1												
2												
3												
4												
5				*362	155	1.52						
6												
7												
8	3.33	226	2.26									
9										329	316	294
10							319	316	309			
11												
12												
13				317	215	120				318	315	310
14												
15				321	318	315						
16	346	251	240									
17	316	294	251							327	305	305
18												
19												
20												
21											310	
22				323	312	310						
23										311	307	303
24												
25	272	249	190									
26				313	212	210						
27												
28				314	310	310						
29	362	291	239									
30											312	
31												

TABLE 7 (Continued)

* open

Sea Level Datum of 1929, S.L.D.

METROPOLITAN DADE COUNTY
WATER CONTROL DIVISION

CORR FACTORS

Hi	Low	Date

STAGE RECORD

☐ Min-Max Gage
☐ Min-Max MK II
☐ Continuous Recorder

Year 81 Gage Designation G-2

	May			June			July			August		
	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low	Hi	Spot	Low
1	218	211	205	253	252	223	285	275	275			
2												
3				[illegible]	[illegible]	[illegible]						
4	222	206	196							3.04	3.04	2.62
5	214	200	192							3.08	3.07	3.03
6	213	199	191				298	284	207	3.11	3.08	3.01
7	217	209	191									
8	285	279	277				284	273	273			
9												
10							279	277	277	3.08	[illegible]	3.02
11	289	267	254	289	279	238					2.92	2.63
12	269	260	253	279	275	275				4.11	3.02	3.00
13										3.02	3.02	2.99
14	2.68	2.62	2.51									
15												
16							280	260	260			
17				277	252	252	260	256	256			
18										4.15	1.86	1.58
19				252	242	242				3.35	1.29	1.20
20							273	272	253	3.69	2.03	1.36
21										3.45	1.58	1.40
22	263	2.41	2.41				275	266	266			
23												
24										2.93	0.53	0.10
25				281	275	241				3.06	0.48	0.25
26	263	2.32	1.82							2.17	0.73	0.25
27										2.81	1.28	0.39
28							271	269	264	3.09	1.59	1.23
29				282	280	267						
30							271	269	268			
31												

TABLE 7. (Continued)

Sea Level Datum of 1929, S.L.D.

Table 8. Coral Gables Canal Stages During the April 1982 Storm Event

Date	Stages (Feet, MSL)
4/23	
4/24	
4/25	
4/26	2.24 - 3.94
4/27	
4/28	3.16 - 3.26
4/29	
4/30	

Tables 9 and 10 include the data for S-25B for the periods in April 1979, August 1980, August and September 1981, and April 1982 when major storm events or flooding occurred in West Miami.

Table 9. Maximum, Average, and Minimum Daily Stages, S-25B (Upstream)

1979 April	Stage (Ft, MSL) Minimum	Average	Maximum
20	-	2.20	-
21	-	2.18	-
22	-	2.18	-
23	-	2.15	-
24	2.15	2.35	2.35
25	-	2.50	-
26	1.15	1.82	2.50
27	1.10	1.97	2.85
28	1.00	1.80	2.60
29	1.20	2.05	2.90
30	1.18	1.99	2.80

1980 August	Stage, (Ft, MSL) Minimum	Average	Maximum
8	-	2.80	-
9	-	2.85	-
10	2.80	2.85	2.90
11	2.58	2.74	2.90
12	2.58	2.76	2.95
13	2.75	2.84	2.93
14	-	2.85	-
15	2.55	2.74	2.93
16	2.55	2.72	2.90
17	2.58	2.75	2.93
18	2.55	2.73	2.92
19	2.55	2.73	2.92
20	2.60	2.70	2.80
21	2.55	2.72	2.90
22	2.52	2.67	2.82
23	2.52	2.71	2.90
24	2.52	2.71	2.90
25	2.52	2.70	2.88

1981 August	Minimum	Average	Maximum
14	-	3.05	-
15	-	3.10	-
16	2.85	3.06	3.28
17	2.58	2.89	3.20
18	1.65	2.26	2.88
19	1.28	1.94	2.60
20	1.00	1.92	2.85

1981 September	Minimum	Average	Maximum
2	0.92	1.70	2.48
3	0.85	1.65	2.45
4	0.90	1.57	2.25
5	0.75	1.40	2.05
6	0.95	1.53	2.12
7	0.80	1.49	2.18
8	0.90	1.44	1.98

Table 9 (Continued)

21	1.05	1.71	2.38	9	0.80	1.51	2.22
22	0.80	1.45	2.10	10	0.80	1.51	2.22
23	0.70	1.39	2.08	11	0.70	1.37	2.05
				12	0.65	1.45	2.25
				13	0.70	1.47	2.25
				14	2.60	3.10	2.85
				15	2.60	2.79	2.98
				September	Minimum	Average	Maximum
				16	2.70	2.85	3.00
				17	1.35	1.95	2.55
				18	1.35	1.95	2.55
				19	1.35	1.77	2.20
				20	1.35	1.92	2.50
				21	1.35	2.02	2.70
				22	1.35	1.95	2.55
				23	1.35	1.97	2.60
				24	1.35	2.15	2.95
				25	2.00	2.50	3.00
				26	1.25	2.00	2.75
				27	1.35	2.05	2.75
				28	1.25	1.90	2.55
				29	1.15	1.77	2.40
				30	1.10	1.72	2.35

Table 10. S-25B Stages During Storm Event of April 1982

Date	Stages (Ft, MSL)
4/23	4.35
4/24	4.15
4/25	2.15
4/26	1.95
4/27	1.95
4/28	1.55
4/29	0.88
4/30	0.98

GROUNDWATER STAGES

The U. S. Geological Survey has several groundwater monitoring wells around the study area. The closest monitoring well with continuous groundwater data (F-179) is located on S.W. 32nd Avenue and 24th Terrace. This monitoring well is east of the project area. Another groundwater monitoring well with continuous record, G-857, existed at S.W. 70th Avenue and 12th Street until 1969. This is the closest monitoring well to the study area. In order to utilize the data from this station to gain insight into the groundwater situation of the project area, a linear correlation model was run between the daily groundwater stages from these two stations. A linear relationship was established between the two stations as follows:

$$G\text{-}(857) = .943 + .8816 \times F(179)$$

The correlation coefficient between the daily values from the two stations was determined to be .919.

Table 11 presents the actual groundwater stage from Well F-179 and the simulated groundwater stage for Well G-857 for the years 1979, 1980, 1981, and 1982.

Table 11. Monthly Groundwater Stages - Well F-179 (Ft, NGVD)

Months	1979	1980	1981
January	2.11	2.20	-
February	1.78	2.24	-
March	1.77	2.18	2.02
April	1.89	2.79	1.97
May	2.75	2.28	1.65
June	2.58	2.56	2.19
July	2.28	2.37	-
August	2.19	2.47	-
September	2.78	2.67	3.67
October	3.23	2.81	-
November	2.60	2.78	-
December	2.41	-	-

Groundwater Stages During Storm Events - Wells F-179 and G-857

YEAR-1968

Month-June

Day	F-179 Ft (NGVD)	G-857 Ft (NGVD)
1	-	4.65
2	-	4.55
3	-	4.25
4	-	7.00
5	4.45	5.56
6	-	5.25
7	-	4.90
8	-	5.50
9	-	5.70

Month-September

Day	F-179 Ft (NGVD)	G-857 Ft(NGVD)
24	-	-
25	3.07	3.64
26	-	-
27	-	-
28	-	-
29	-	-
30	3.65	4.16

Table 11 (Continued)

10	3.91	6.00
11	-	6.50
12	-	6.05
13	-	6.00
14	-	5.10
15	4.34	4.75
16	-	4.60
17	-	4.20
18	-	4.15
19	3.23	3.79
20	-	-

Groundwater Stages During Storm Events - Wells F-179 and G-857

YEAR-1979

Month-June

Day	F-179 Ft (NGVD)	G-857 Ft (NGVD
24	1.55	2.30
25	3.42	3.95
26	3.42	3.95
27	3.31	3.86
28	3.20	3.76
29	3.18	3.74

Month-September

Day	F-179 Ft (NGVD)	G-857 (Ft (NGVD)
25	2.84	3.46
26	2.99	3.58
27	3.12	3.69
28	3.26	3.81
29	3.41	3.95
30	3.67	4.17

YEAR-1980

Month-April

Day	F-179 Ft (NGVD)	G-857 Ft (NGVD)
5	2.52	3.06
6	2.48	3.13
7	2.90	3.50
8	2.97	3.56
9	2.99	3.58
10	2.99	3.58
11	2.95	3.54

Month-July

Day	F-179 Ft (NGVD)	G-857 Ft (NGVD)
13	2.27	2.94
14	2.27	2.94
15	2.26	2.93
16	2.26	2.93
17	2.26	2.93
18	2.26	2.93
19	2.27	2.94
20	2.28	2.95
21	2.38	3.04
22	2.65	3.28
23	2.66	3.29
24	2.61	3.24
25	2.53	3.17

Month-August

Day	F-179 Ft (NGVD)	G-857 Ft (NGVD)
9	2.19	2.87
10	2.14	2.82
11	2.16	2.85
12	2.21	2.89
13	2.41	3.07
14	2.41	3.07
15	2.35	3.01
16	2.30	2.97
17	2.28	2.95
18	2.30	2.97
19	2.54	3.18
20	2.54	3.18
21	2.83	3.43
22	2.84	3.45
23	2.81	3.42
24	2.77	3.38
25	2.72	3.34

Table 11 (Continued)

YEAR-1981

Month-August			Month-September		
Day	F-179 Ft (NGVD)	G-857 Ft (NGVD)	Day	F-179 Ft (NGVD)	G 857 Ft (NGVD)
15	2.36	3.02	3	3.04	3.62
16	2.89	3.49	4	2.99	3.58
17	3.56	4.08	5	2.95	3.54
18	5.18	5.51	6	2.88	3.48
19	4.97	5.32	7	2.86	3.46
20	4.70	5.08	8	2.86	3.46
21	4.50	4.91	9	2.92	3.51
22	4.22	4.66	10	2.93	3.52
			11	2.90	3.50
			12	2.85	3.45
			13	2.81	3.42

Year 1981

Month-September

Day	F-179 Ft (NGVD)	G-857 Ft (NGVD)
14	2.77	3.38
15	2.90	3.50
16	2.90	3.50
17	2.84	3.45
18	2.84	3.45
19	2.78	3.39
20	3.71	4.21
21	3.71	4.21
22	3.55	4.07
23	3.50	4.02
24	3.38	3.92
25	6.01	6.24
26	6.68	6.83
27	6.79	6.92
28	6.38	6.65
29	5.76	6.02
30	5.25	5.57

Table 12. Groundwater Stages During April 1982 Storm Events - Well F-179, and the Simulated Stages for Well G-857

Date	F-179 (Feet)	G-857 (Feet)
4/23/82	2.02	2.72
4/24/82	3.95	4.42
4/25/82	4.07	4.53
4/26/82	4.63	5.02
4/27/82	4.65	5.01
4/28/82	4.22	4.66
4/29/82	4.16	4.60
4/30/82	3.94	4.41

The groundwater stages show that the water level was above the land surface during several past storm events. As there is no monitoring well in the project area, the District has provided the City of West Miami with groundwater measuring equipment which is to be installed in a well located on a school property.

ANALYSIS OF CRITICAL FLOODING EVENTS

Critical flooding events were defined by superimposing the groundwater and canal stages on the minimum ground elevation of the area for given storm events. As this analysis was based on the daily records, groundwater stages greater than those that were plotted may have occurred for a few hours during a particular day. The stages should be exact, however, from one day to the next. Performance analysis was then made for several past hydrologic events to derive conclusions regarding the operation of District control structures.

Storm Event of April 1982

The District prepared a preliminary report of the rainstorm of April 23-26, 1982[12]. As the report is regional in nature, however, it could not be used for this site specific analysis of West Miami. Rainfall distributions from the two stations in the West Miami area are presented in Table 3. Stages from the Coral Gables Canal are presented in Table 8, the upstream stage of S-25B in Table 10, and the actual groundwater stage and the simulated stage in Table 12. The minimum ground elevation of the area, along the western portion, is 5.0 ft. MSL. Figure 6 presents the superimposition of the groundwater and canal stages for this storm event.

The plot depicts that the lowest elevation area of West Miami had standing water for at least two days. The data plotted are end-of-the-day data. Groundwater stages may have been higher during certain hours of the day. Canal levels were significantly lower than groundwater stages. The average canal stage in the Coral Gables Canal was at 3.0 ft MSL; however, S-25B was

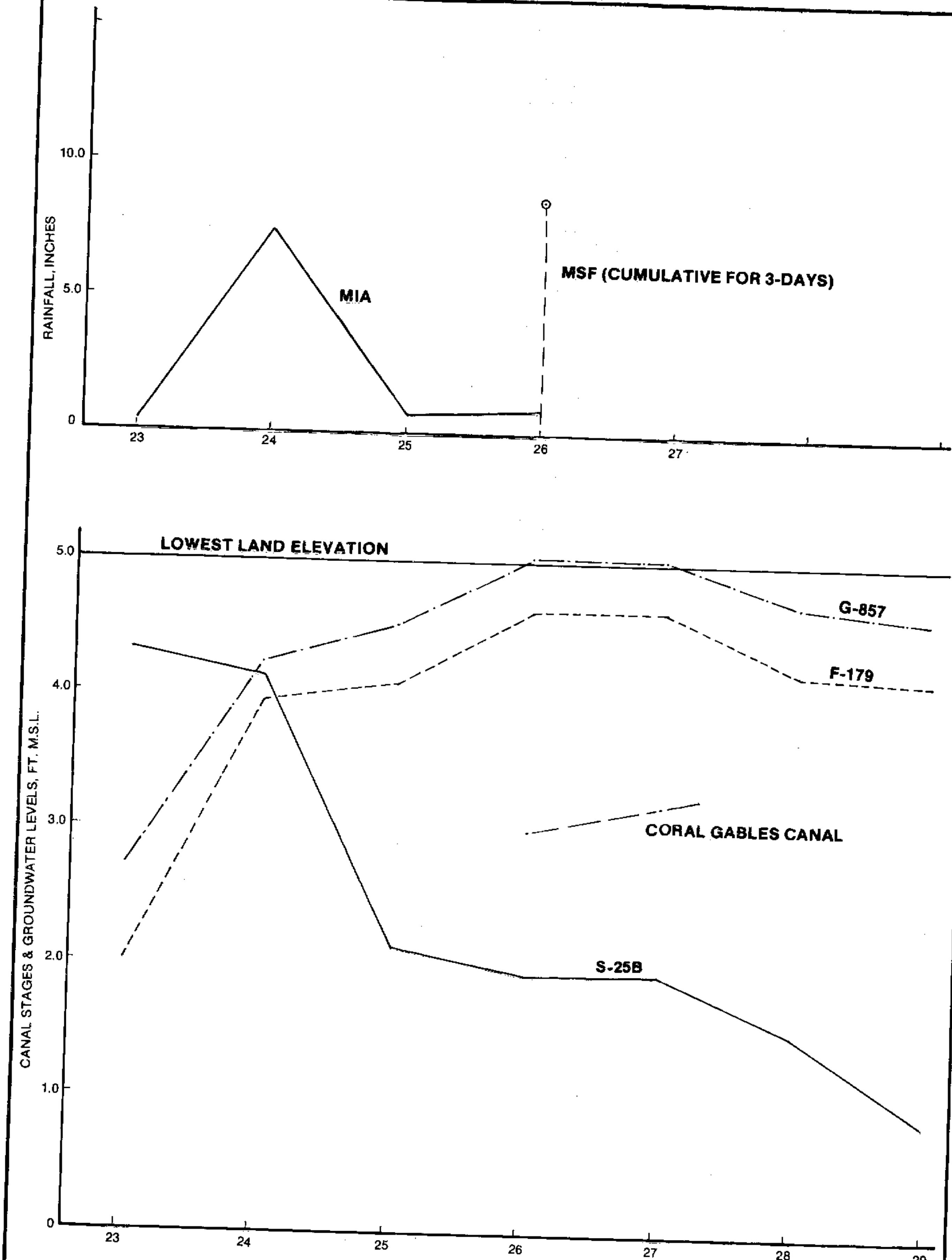


Figure 6 RAINSTORM OF APRIL 23-26, 1982

fully open and the upstream stage was below 2.0 ft. MSL. Therefore, there was a significant hydraulic head between the groundwater elevation and the canal stages. This did not help the City of West Miami's flooding problem. In order to reduce the flooding, the city constructed a temporary outfall structure at the Coral Way ditch and pumped water from one of the catch basins to the ditch. Within 48 hours they were able to reduce the groundwater stages by as much as 2.0 feet. This last flooding episode clearly shows that lowering of the canal stages alone does not solve the West Miami flooding problem.

Storm Event of September 1981

Groundwater stages and the canal levels for the rainfall event of September 3-29 are presented in Figure 7. Up to the 23rd of the month, the study area already had received more than 8.37 inches of rainfall. S-25B stages were fluctuating between 2.0 and 2.5 ft. MSL. Groundwater stages were already higher than 3.0 ft. MSL. On the 25th of the month the study area received another 4.36 inches of rainfall. Even though the canal stages were lowered to 2.2 ft. MSL (19th of the month) before the rainfall of the 25th, groundwater stages jumped to almost 7.0 ft. MSL. The low-lying area was under water for more than 10 days. On the 29th of the month, the area was still under water. On that particular day, S-25B stage was at 2.38 ft. MSL. There was a hydraulic head of 2.4 ft. MSL from the groundwater to the canal. In other words, the storm water could not be removed from the basin quickly, and it took more than 10 days for the groundwater stages to recede.

Rainstorm of August 16-21, 1981

During a 5-day period in August (16-21) the study area received anywhere from 8.13 to 12.56 inches of rainfall. Even though the canal stages were lowered, the low-lying area of the City of West Miami was under water for more

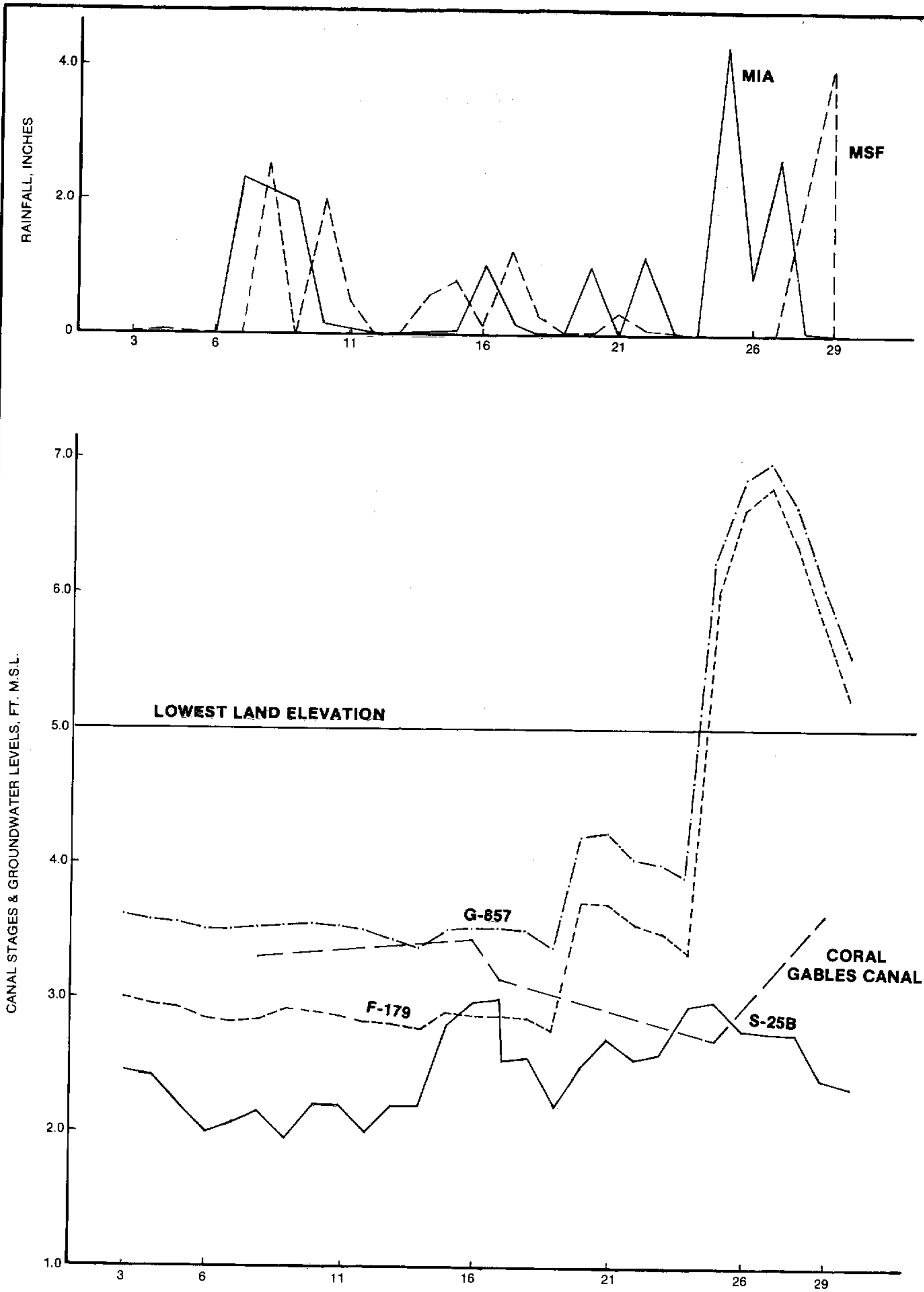


Figure 7 RAINSTORM OF SEPTEMBER 3-29, 1981

than 4 days. Figure 8 shows that during a 2-day period (20-21 August) S-25B stage dropped by 0.77 ft., whereas the groundwater stage dropped by only 0.42 ft. This was during the period when canal stage was at almost optimal level and then was dropped to 2.0 ft. MSL. This confirms the fact that there is a slight (but ineffective in terms of alleviating flooding in West Miami) drop in the groundwater stage when canal levels are dropped below optimal levels.

Rainstorm of April 24-27, 1979 (Figure 9)

During the four day period, the study area received between 12.37 to 16.24 inches of rain (Figure 9). On the 25th of the month, Miami International Airport received 14.85 inches and the Miami Field Station received 11.64 inches. This one day storm event exceeded the return frequency of 1-in-100 years, and occurred during the dry season when the groundwater elevation (at F-179) was lower than the Coral Gables Canal stages. No flooding occurred in the basin from this single, isolated dry month storm event.

Hydrologic Events of June 1 - 19, 1968

In the past, this event received considerable attention. The former Mayor of the City of West Miami (Edmund P. Cooper) wrote a letter to the District charging that the water conservation areas were the major cause of this 1968 flooding event. Additionally, a letter was also sent to the Hon. Dante B. Fascell, Congressman from Miami. The District's field investigation (Figure 10) concluded as follows:

1. There was no positive storm drainage to primary canals.
2. The seepage drains which had been provided were not adequate to carry off the storm water.

In this current report, the analysis of this particular event has been re-examined. Presented in Figure 10 is the rainfall that fell on the area, as

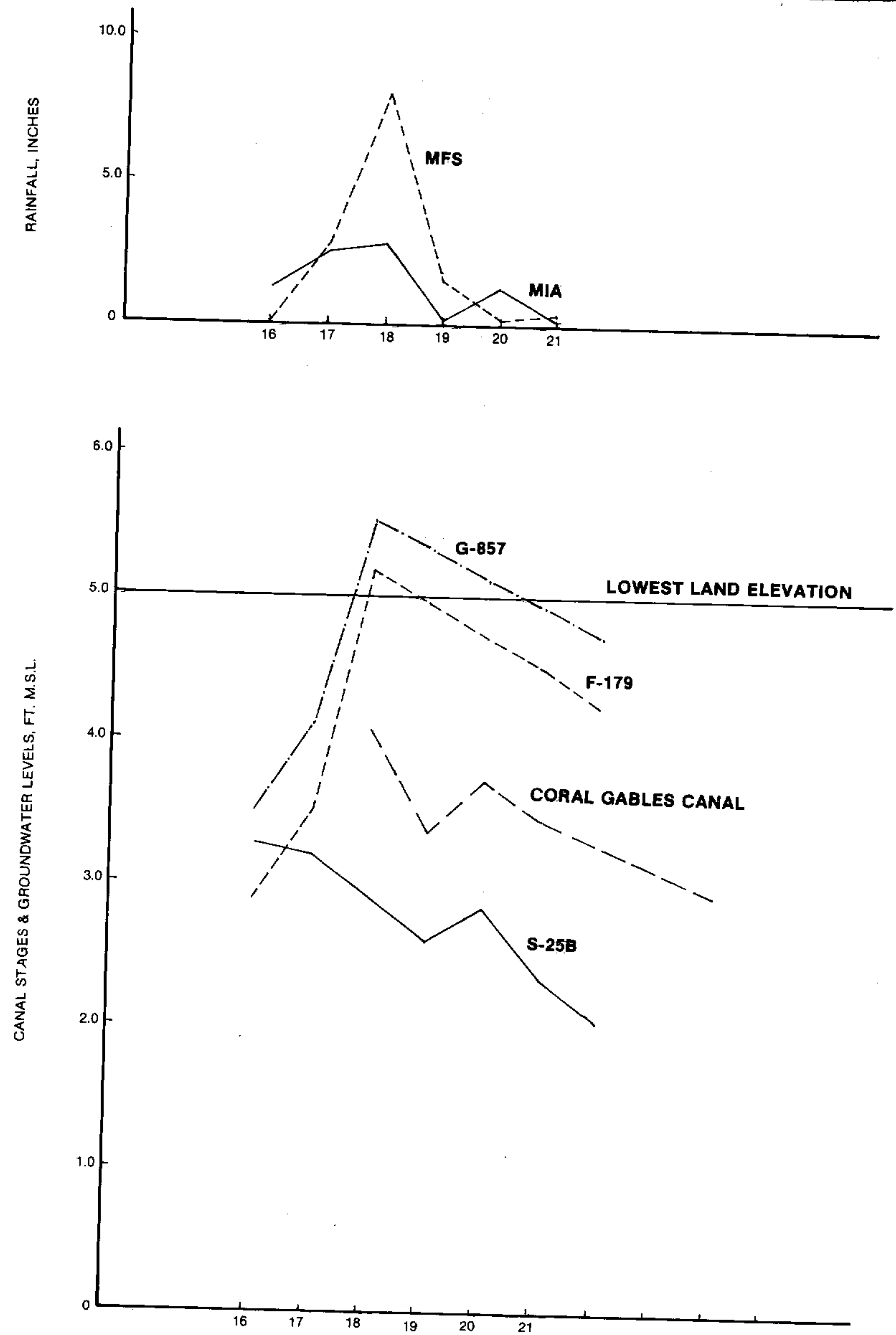


Figure 8 RAINSTORM OF AUGUST 16-21, 1981

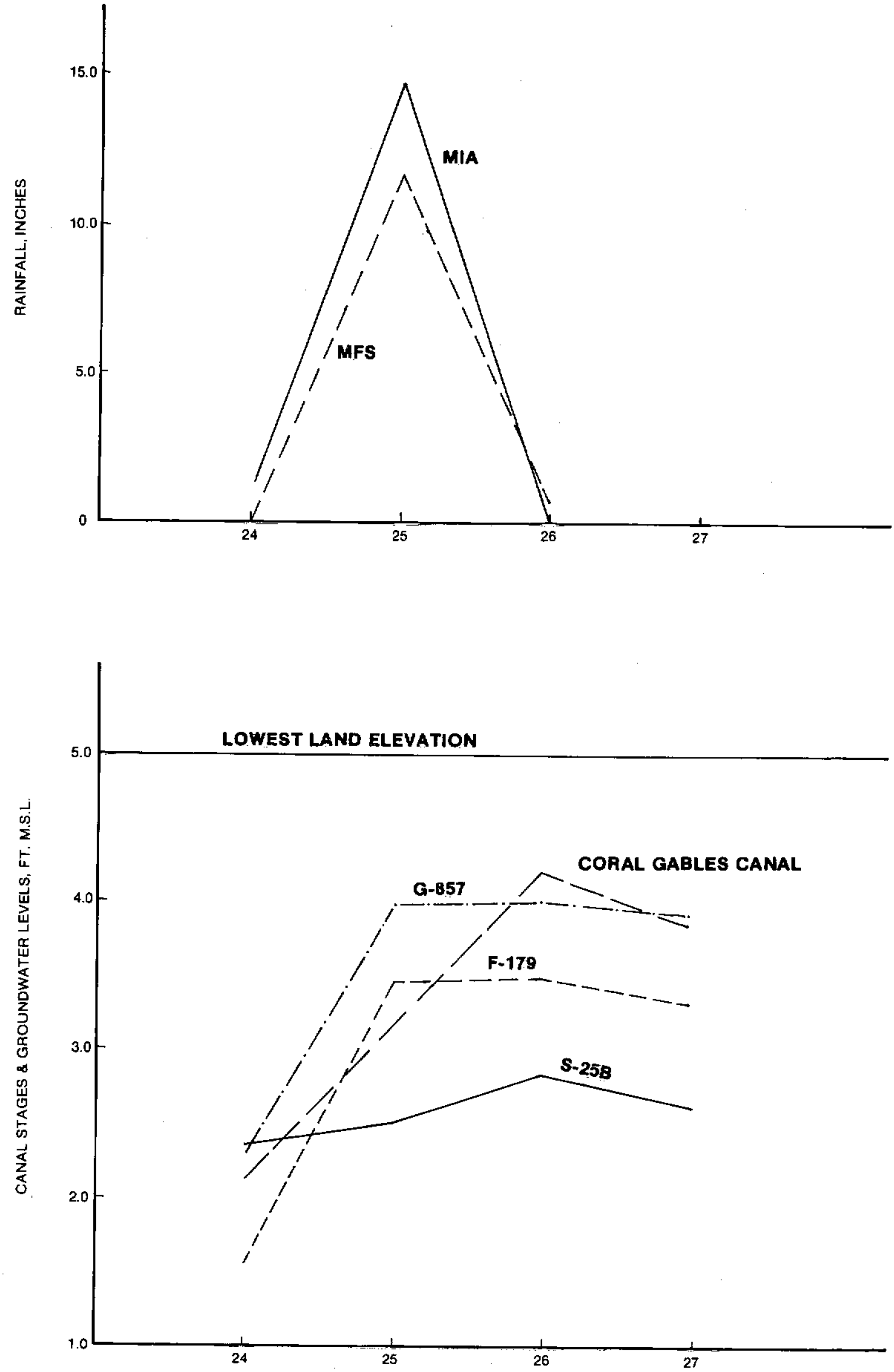


Figure 9 RAINSTORM OF APRIL 24-27, 1979

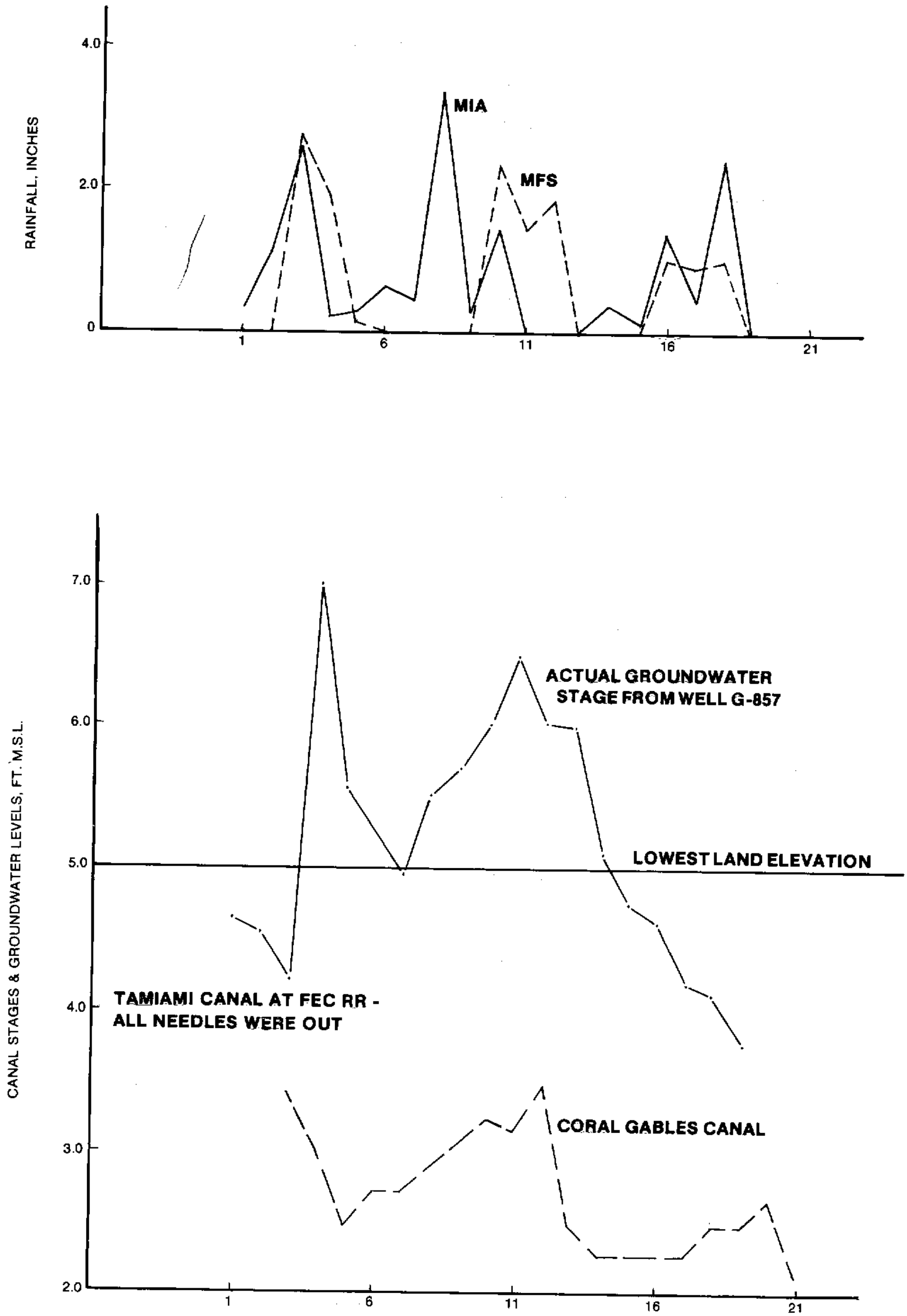


Figure 10 STORM EVENT OF JUNE 1-20, 1968

well as groundwater stages and Coral Gables Canal stages. Tamiami Canal, near the FEC RR, was fully open.

The total rain that fell in the study area during the 20-day period varied from 15.97 inches at Miami International Airport to 13.57 inches at the Miami Field Station. This rain fell during the period when the basin had already received typical south Florida rain. On the 2nd and 3rd of the month, the study area received another 3.75 inches of rain. On the 3rd of the month, Coral Gables Canal had a stage elevation of 3.42 ft. MSL. The groundwater stage in the basin started to rise from the 3rd of the month. The study area was under water for 14 days. The canal was maintained at the lowest stage (fully open - all needles were out), groundwater stages did not drop rapidly, even though there was enough hydraulic head between the groundwater and the canal stage. Due to lack of positive outfall, it took 14 days for the groundwater to recede.

OBSERVATIONS

Analysis of several rainstorm events in the West Miami area reveals that flooding occurs more often from long durations of rainfall. Even though the structures are fully open, it takes many days for the groundwater to reach the canal and recede. As stated earlier, when the headwater elevation rises to 3.0 ft MSL, the gates open automatically at the rate of six inches per hour. In past years, however, on many occasions gates were opened manually before they reached the headwater elevation of 3.0 ft. MSL.

Analysis also shows that lowering of the canal stages will help West Miami to some extent. This is due to two factors: 1) If the canal stages are lowered, than there is more storage in the system, and 2) A higher hydraulic head difference between the groundwater and the canal is created. Lowering of the canal stages alone, however, is not sufficient to alleviate

West Miami's reoccurring flooding problems as evidenced during the April 1982 event.

Several alternatives (both regional and local in nature) were evaluated to help West Miami solve its flooding problems.

PART 2. SURFACE WATER MANAGEMENT ALTERNATIVES

There are several alternatives (both regional and local in nature) which can be utilized to solve West Miami's flooding problems. They are as follows:

1. Placement of secondary control structures upstream of the present structures and lowering the stages downstream to 1.8 ft. MSL.
2. Lowering of the stages at the existing structures.
3. Removal of sheet pile structures and replacing them with more efficient structures.
4. Injection of stormwater into sub-surface reservoirs.
5. Inter-connection of the existing catch basins and placement of an outfall structure in the Coral Way ditch (DOT's canal).

Alternatives 1, 2, and 3 are regional in nature. The function of these alternatives is to create additional storage space for runoff generated during storm events. However, analysis of the past storm events indicates that reduction in canal stages alone (Alternative 2) would not significantly reduce the amount or the duration of flooding in West Miami. Therefore, emphasis will now be placed on evaluating the alternative of placing secondary control structures, maintaining higher heads behind these structures, and lowering the stages at the present structures.

Alternatives 4 and 5 are local in nature. These alternatives rely primarily on local solutions to alleviate local flooding problems. Alternative 4 examines the idea that runoff generated in a basin can be injected and stored in the subsurface formation of the basin itself, which is regarded as a vast storage reservoir. Alternative 5 is the method of disposing of runoff water from the basin in the safest and quickest possible way.

Alternative 1. Lower Canal Stages/Add New Secondary Structures

Alternative 1 serves the same purpose as Alternative 2 except that it allows for maintaining higher heads above the secondary control structures. Presently, this alternative is preferable to alternative 2, as optimal water levels must be maintained to protect the Metro-Dade Water & Sewer Authority wellfields from saltwater intrusion.

A surface water-groundwater interface model was calibrated to evaluate the effect that placement of secondary control structures would have on the groundwater elevation of the area. Results derived from the model show that due to a lower groundwater elevation in the area (1.8 ft. as compared to 2.8 ft.), less of the area ponds. Additionally, as the canal stage is lowered by 1.0 ft. downstream, the groundwater stage reduces by 0.2 ft. (see Appendix for the computer study).

It can be stated, based on the model results, that Alternative 1 will somewhat lessen the areal extent of flooding and also maintain lower groundwater stages in the area. However, this solution alone is expensive and, by itself, will not be enough to solve the City of West Miami's flooding problems. Additionally, due to high groundwater stages behind the secondary control structures, the area west of West Miami will experience more severe flooding problems than encountered in the past.

Alternative 2. Lower Control Stages

This alternative has been practiced by the District during periods when the area receives high amounts of rainfall. At present, due to the stratigraphic location of the Miami-Dade S&WA wellfields, canal stages and, in turn, groundwater stages, cannot be lowered on a permanent basis especially during the dry months. As with Alternative 1, this alternative by itself will not solve West Miami's flooding problem.

During the April 1982 storm event, S-25B gates were open full; however, as lowering of the canal stages was not enough, the city had to pump water from one of the catch basins and discharge it to the Coral Way ditch. With this combination, they were able to lower the groundwater stages in 48 hours to a safe stage.

Alternative 3. Replace Existing Structures

It was stated earlier in the text that a sheet pile structure is located on the Coral Gables Canal. During storm events, these sheet piles are difficult to operate. The designed discharge rate of G-97 is only 640 cfs, which is 40% of the standard project flood. Dialogue has already started with the Corps of Engineers (Interagency Meeting of January 27, 1982) to replace this structure with a larger and more efficient automatic structure. The Corps of Engineers stated they will verify project authorization and explore available options. With the new, larger structure in place, the District will be able to discharge more water to the ocean than it presently can. This will enable the groundwater stage to recede faster than it does now. However, as in Alternatives 1 and 2, this enlargement of discharge facility will not solve West Miami'a flooding problem by itself.

Alternative 4. Inject Storm Water Into Subsurface Reservoirs

Storm water can be injected into the underground formation via deep wells. According to Department of Environmental Regulation Chapter 17-28 rules for underground injection control, storm water injection wells are classified as Class V wells. Criteria and standards, as they apply to Class V wells, are presented in the following pages.

This alternative is a viable solution to West Miami's recurring flooding problem. It is, however, in the first place a very costly solution, and secondly, with EPA's designation of the Biscayne aquifer as the sole source, it might be difficult to get an operating permit from the DER.

PART V - CRITERIA AND STANDARDS FOR CLASS V WELLS

17-28.51 General

(1) Part V sets forth criteria and standards to regulate all injection wells not regulated in Parts I-IV.

(a) Generally, wells covered by this Part inject non-hazardous fluids into or above formations that contain underground sources of drinking water. It includes all wells listed in Section 17-28.03(1)(e) but is not limited to those types of injection wells.

(b) It also includes wells not covered in Class IV that inject natural and manmade radioactive materials in concentrations in water above natural background, provided these concentrations do not exceed current drinking water standards in Chapter 17-22, F.A.C.

(2) Classification of Class V Wells

Various types of Class V wells that exist or may exist in Florida are grouped together by expected water quality of the injected fluid, to facilitate determination of permitting, operating, and monitoring requirements for these wells. The groups are:

(a) Group 1 - Those wells associated with thermal energy exchange processes, which include air conditioning return flow wells and cooling water return flow wells. Cooling water return flow wells may be part of a closed-loop system, with no hazardous additives, or part of an open-loop system that may use additives.

(b) Group 2 - Class V wells in Group 2 include recharge wells, saltwater intrusion barrier wells, connector wells, and subsidence control wells.

(c) Group 3 - Wells in this group are part of domestic waste treatment systems, and include swimming pool drainage wells.

(d) Group 4 - Group 4 wells are non-hazardous industrial and commercial disposal wells, and include septic system wells, laundry waste, dry wells, sand backfill wells, and nuclear disposal wells injecting only low level radioactive wastes.

(e) Group 5 - Group 5 wells include lake level drainage and stormwater drainage wells.

(f) Group 6 - Geothermal wells and 'other' wells are included in this group.

(3) The use of any Class V well for injection shall not present a hazard to any existing or future use of an underground source of drinking water.

17-28.52 Well Construction Standards for Class V Wells

(1) The variety of Class V wells and their uses dictate a variety of construction designs consistent with those uses, and precludes specific construction standards for each type of Class V well outlined in this rule. However, a well must be designed and constructed for its intended use, in accordance with good engineering practices, and the design and construction must be approved by the Department.

(2) The Department may apply the design criteria for Class I wells (Part II of this rule) and other factors to the construction of Class V wells.

(3) Class V wells shall be constructed so that their intended use does not violate the water quality standards of Chapter 17-3, F.A.C. Migration or mixing of aquifers of substantively different water quality (through the construction or use of a Class V well) shall be prevented by preserving the integrity of confining beds between these aquifers through cementing or some other method acceptable to the Department.

(4) All Class V wells shall be constructed by a licensed water well contractor.

17-28.53 Operating Requirements for Class V Wells

(1) All Class V wells shall be operated in such a manner that they do not present a hazard to an underground source of drinking water.

(2) Pretreatment may be required for existing wells to insure that the injected fluid does not violate water quality standards.

(3) The Department shall impose operating requirements on Group 1 - cooling water return flow wells on an open-loop system, with additives; Group 3, except for swimming pool drainage wells; Group 4; and Group 6.

(4) The Department may impose operating requirements on Group 2 and 5.

17-28.54 Monitoring Requirements for Class V Wells

(1) The need for monitoring is determined by the type of well, nature of the injected fluid, and water quality of the receiving aquifer. The Department may impose monitoring requirements for Groups 1, 2, 3, 5 and 6.

(2) The nature of the fluid being injected into or above an underground source of drinking water from Group 4 wells is such that the Department shall require monitoring for wells in this group.

(3) The Department shall determine the frequency of monitoring based on the location of the well, the nature of the injected fluid and, where applicable, the requirements of Chapters 17-6 and 17-19, F.A.C.

17-28.55 Reporting Requirements for Class V Wells

(1) Reporting requirements are determined by the type of well and nature of injected fluid. When necessary and where

applicable, reporting shall be in accord with Chapters 17-6 and 17-19, F.A.C.

(2) Reporting for Group 1 - cooling water return flow wells on an open-loop system, with additives; Group 3, except for swimming pool drainage wells; reporting for Group 4 and Group 6 will be required.

(3) The Department may require reporting for Groups 2 and 5.

17-28.56 Plugging and Abandonment

(1) The Department may order a Class V well plugged and abandoned when it no longer performs its intended purpose, or when it is determined to be a hazard to the ground water resource.

(2) Prior to abandoning Class V wells the well shall be plugged with cement in a manner which will not allow movement of fluids between underground sources of drinking water. The proposed plugging method and type of cement shall be approved by the Department. Placement of the cement shall be accomplished by any recognized method which is acceptable to the Department.

PART VI - CLASS V WELL PERMITTING

17-28.61 General

(1) Underground injection through a Class V well which began operation after the effective date of this rule is prohibited except as authorized by permit issued under this Part. The construction or modification of any well required to have a permit under this Part is prohibited until the permit has been issued. In addition to the specific provisions of this Part, the general permitting provisions of Chapter 17-4, Part I, F.A.C., shall apply.

(2) No UIC authorization by permit or rule shall be allowed where a Class V well causes or allows movement of fluid containing any contaminant into underground sources of drinking water, and the presence of that contaminant may cause a violation of any primary drinking water regulation under Chapter 403, F.S. and Chapter 17-22, F.A.C. or which may adversely affect the health of persons.

(3) If at any time the Department learns that an existing Class V well may cause a violation of primary drinking water regulations under Chapter 403, F.S. or Chapter 17-22, F.A.C., the Department sHall:

(a) Require a permit for such Class V well;

(b) Order the injector to take such actions including where required, closure of the injection well as may be necessary to prevent the violation; or

(c) Take enforcement action.

(4) Whenever the Department learns that a Class V well may be otherwise adversely affecting the health of persons,- the Department may prescribe such actions as may be necessary to prevent the adverse affect, including any action authorized under paragraph (2) of this Section.

(5) Notwithstanding any other provision of this Section, the Department may take emergency action upon receipt of information that a contaminant which is present or is likely to enter a public water system may present an imminent and substantial endangerment to the health of persons.

(6) The owner or operator of any new or existing Class V well shall, within one year of the effective date of an underground injection control program, notify the Department of the existence of any well meeting the definitions of Class V under his control, and submit the inventory information required in paragraph (7) below.

(7) As part of the inventory, the Department shall require at least the following information:

(a) Facility name and location, including a plot plan showing location of well(s);

(b) Name and address of legal contact;

(c) Ownership of facility;

(d) Nature and type of injection wells, including installed dimensions of wells and construction materials;

(e) Operating status of injection wells, including history of injection;

(f) Volume of injected fluid;

(g) Nature of injected fluid;

(h) Description of injection system, including monitoring well(s), if any.

(8) A group of similarly designed injection wells owned and operated by the same applicant serving the same purpose may be permitted as a system rather than as individual wells.

(9) The owner of a Class V well shall be responsible for notifying the Department of a change in ownership. Until such time as notice of change in ownership is submitted, the owner

reflected on the permit/clearance shall be responsible for the operation of the well and ior damages resulting from improper operation of the wells.

17-28.62 Construction/Clearance Permit

(1) All Class V wells must obtain a two-part Construction/ Clearance Permit. The applicant must submit to the Department at least the following information before receiving permission to construct:

(a) Facility name and location;

(b) Name and address of legal contract;

(c) Ownership of facility;

(d) Name and address of driller;

(e) Description and use of proposed injection system, including type and construction of injection wells, nature and volume of injected fluid, and any proposed pretreatment.

(2) Upon completion of the well construction, the driller shall certify with the Department that the well has been completed in accordance with the approved construction plan, and submit any other additional information required by the construction permit before the well can be put into service.

(3) The Department may issue a clearance letter or authorization to use, which is non-renewable and non-expiring. The clearance letter may contain operating and reporting requirements.

(4) Initial and/or periodic testing of the well may be required for all Class V wells.

17-28.63 Operating Permit

(1) In addition to a Construction/Clearance Permit, permittees of these wells shall obtain an operating permit for:

(a) Cooling water return flow wells on an open-looped system, with additives; Group 3 wells except for swimming pool drainage wells; and Group 4 and 6 wells.

(b) Class V wells in Groups 2 and 5 do not require an operating permit.

(2) Operating permits shall be issued for a period not to exceed five years.

(3) At least 60 days prior to expiration of an operating permit, the permittee shall apply for renewal of his permit.

17-28.64 Plugging and Abandonment Permit

(1) The permittee of any Class V well shall apply for a Plugging and Abandonment Permit when the well is no longer used or usable for its intended purpose or other purpose as approved by the Department. The application shall include the proposed plugging plan and justification for abandonment.

(2) Upon completion of plugging and abandonment procedures, the engineer of record shall provide certification of completion in accordance with the plans and specifications.

(3) The permittee of any Class V well may be required to provide evidence, such as a sealed copy of certification from the county clerk, that a surveyor's plot of the location of the abandoned well has been recorded in the county courthouse property records.

CODING: Words <u>underlined</u> are additions; words in ~~struck through~~ type are deletions from existing law.

Alternative 5. Inter-connection of the Existing Catch Basins and Placement of an Outfall Structure in the Coral Way Ditch (DOT Canal)

This alternative examines the effect of modifying direct surface discharge in order to alleviate the flooding problem of the City of West Miami. At present, the City of West Miami has no direct outfall facility. Runoff water generated from storm events enters the french drain system, reaches the groundwater table, and starts moving slowly toward the point of discharge (primary canals).

Discharge of groundwater to the primary canals is dependent on the hydraulic properties of the water table aquifer. These properties include the transmissivity, the hydraulic gradient (difference in canal and the groundwater table stages) and the width through which the groundwater flow leaves the basin. Examination and analysis of several past storm events reveals that even though the District structures were open, and sufficient hydraulic head existed between the groundwater and the canal stages, it generally took many days for the groundwater stage to recede. However, during the storm event of April 1982, groundwater stages were lowered by more than 2 feet within 48 hours by a combination of groundwater flow and direct discharge from the basin.

The City of West Miami constructed a temporary outfall facility and discharged water from one of the catch basins to the Coral Way Ditch at a rate of 600 gpm (1.33 cfs). It should be stated that District Structure 25B was open during this event also. This combination of direct discharge and the groundwater discharge solved West Miami's flooding problem within 48 hours. This clearly indicates that some positive outfall capability must be provided by the City of West Miami for future flood problems.

Preliminary economic calculations for this alternative and comparison with the cost of other alternatives indicates this to be the most cost effective approach.

CONCLUSIONS

This study clearly demonstrates the need of a positive outfall structure to alleviate flooding conditions in the City of West Miami. Based on the analysis of several water management alternatiaves, the most economical solution for West Miami is the interconnection of all the catch basins and extension of an outfall (pipe) structure at Coral Way ditch. This recommendation, for construction of an outfall structure, is not new. As far back as 1968, after the June storm, the District informed West Miami city officials that the seepage drains were not adequate to carry off storm water. The Comprehensive Land Use Plan for the area, as prepared by the city planners, also pointed out that under the heading of "drainage element" the present system of storm water removal (through the seepage trench) could not adequately handle the large amounts of rainfall which the area receives. The Comprehensive Land Use Plan also recommended that additions to the system (including structures) must accompany or take precedence over the infiltration technique for effective drainage.

REFERENCES

1. City of Coral Gables Planning Dept. ________. City of Coral Gables Comprehensive Plan. 1978 - 2000.
2. City of South Miami, 1981. Comprehensive Plan.
3. Hall, J.E., 1981. Summary of Hydrologic Data Collected During 1979 in Dade County, Fl., U.S.G.S. Provisional Data.
4. Kohout, F.A., and Hartwell, J. H., 1967. Hydrologic Effects of Area B Flood Control Plan on Urbanization of Dade County, Florida. Bureau of Geology, R.I., No. 47.
5. Leach, S.D., and Grantham, R.G., 1966. Salt-Water Study of the Miami River and its Tributaries, Dade Co., Fl. Fl. Bureau of Geology, R.I. #45.
6. Pool, S.E., 1978. Natural Environment and Resources. Dade County's Planning Process and Factors in Evaluating Amendments.
7. Sherwood, C.B., and Leach, S. D., 1962. Hydrologic Studies in the Snapper Creek Canal Area, Dade County, Florida. Florida Bureau of Geology, R. I. #24
8. South Florida Water Management District, 1979. Preliminary Report on the Severe Storm of April 24-25, 1979.
9. South Florida Water Management District, April 1977. Water Use & Supply Development Plan, Volume II, Plan Rationale.
10. USDA, Soil Cons. Service. Soil Survey, Dade Co., Florida, 1947, #4

APPENDIX

EVALUATION OF PROPOSED ALTERNATIVES TO MINIMIZE FLOODING IN THE WEST MIAMI AREA

PURPOSE

Two spring storm events, April 24-25, 1979, and April 23-26, 1982, as well as a summer event, the August 16-20, 1981 storm, were benchmarks used to investigate alternatives to minimize flooding in the West Miami area. The canal system for the study area is shown in Figure 1. The stages maintained at the canals during the simulation of the storm events are also indicated in Figure 1. This system was the basis for which the following alternatives were compared and evaluated:

Alternative 1: A secondary structure is imposed at the intersection of C-4 and the Coral Gables Canal. C-4 upstream has a minimum stage of 4.0 ft. m.s.l. (see Figure 2). The minimum stage at S-25B is lowered from 2.2 ft. m.s.l. to 1.8 ft. m.s.l. The coastal structure at the Coral Gables Canal is moved farther downstream (south of Red Road, see Figure 2), and the minimum stage modified from 2.2 ft. m.s.l. to 1.8 ft. m.s.l.

Alternative 2: The same as Alternative 1, except that the secondary structure is moved upstream to the intersection of Snapper Creek and C-4 Canals, near the West Dade Expressway (see Figure 3).

I. Surface Modeling

A. Surface Ponding

At the beginning of each day, rainfall is read into the model. The rainfall is divided uniformly over hourly time steps and added to the surface ponding value corresponding to the previous time step. This process is repeated every time step. The surface ponding is initialized as 0.0 for every node point.

B. Overland Flow

Manning's equation is used to compute overland flow in the model. The roughness coefficient used in the model is considered a function of land use type. The flow is treated as flow through a wide open channel; thus, the hydraulic radius is approximately by the water depth. The hydraulic gradient is estimated using the following relationship:

$$HG = \frac{HU-HD}{DX} \quad \text{or} \quad HG = \frac{HU-HD}{DY}$$

where HU = ELLS(X,Y) + POND(X,Y)

and HD = ELLS(LX,LY) + POND(LX,LY)

HG is the hydraulic gradient

HU = Upstream stage

HD = Downstream stage

DX = Distance in the east-west direction

DY = Distance in the north-south direction

ELLS(X,Y) = elevation of land surface, in feet m.s.l. at upstream node point

POND(X,Y) is the ponding depth, in feet above land surface at upstream node point. LX,LY are X and Y coordinates at downstream node point.

Since Manning's equation is one-dimensional, and used with a two-dimensional groundwater equation, overland flow is computed twice in each time step, once in the north-south direction, and once in the east-west direction.

C. Channel Flow

The channel flow routine is a mass balance procedure that sums the inflows and outflows of a canal during one time step to determine the position of the water surface at the end of the time step.

The flow processes included are:

1. Structure discharge (COUT)
2. Groundwater movement into or out of canal (CGINF)
3. Overland flow in or out of canal (VOLOV)

A canal is a continuous channel reach, bounded by upstream and downstream structures. The following assumptions were incorporated:

1. The width of a canal is constant.
2. A simple weir approximation of outflow is used based on the canal stage and the assumed width of the hypothetical weir.
3. If the canal stage is equal to the minimum stage at the structure, the outflow is zero. In this study the canals are not allowed to fall below the minimum stage, but are allowed to fluctuate above the minimum level.

D. Evapotranspiration

The ET losses are based on potential ET (PET) and a linear reduction equation to calculate actual ET based on the depth to the water table. PET varies with land use and time of year. The model uses 12 monthly PET values for each of the four land use types: 1-urban, 2-agricultural, 3-swamp, and 4-vacant. Each land use has a shallow root zone (SRZ), and a deep root zone (DRZ) that are used to determine the actual amount of ET in the following way:

ET = PET when the water table is at or above the shallow root zone.

ET = zero when the water table is below the deep root zone.

ET = PET * (DRZ-DPH)/(DRZ-SRZ) when the water table is between the shallow and the deep root zones where DPH is the distance from the land surface to the water table (ELLS(X,Y)-H(X,Y)).

The PET and the shallow and deep root zone values for each land use are shown in Table 1.

II. Groundwater

Groundwater was based on the finite difference approximation of two dimensional transient equation for unconfined aquifers:

$$Tx \frac{\partial^2 h}{\partial x^2} + Ty \frac{\partial^2 h}{\partial y^2} = S \frac{\partial h}{\partial t} + RCHG$$

Where Tx and Ty are transmissivity values in the x and y direction, respectively.

S is the storage coefficient assumed to be 0.2.

h is the hydraulic head.

RCHG is the recharge which includes wellfield pumpage, groundwater seepage to or from canals, surface ponding, and ET.

III. Description of Model Runs

Model Area

The model area is about 150 square miles bounded north by C-7, west by Snapper Creek Canal, and extension of C-2, south by C-2 and east by the coastline. The grid resolution is one-third mile in the north-south and east-west direction. The area includes C-6, C-7, Tamiami east, Coral Gables Canal, and C-2 basins.

Model Runs

Three runs, one for each alternative and one for the present system were done for the three storm events mentioned earlier. The time step was one hour.

1. For the April 1979 storm, the average yearly lowest groundwater table for the period 1960-1975, published by USGS, is input.
2. For the April 1982 storm, the groundwater table at the end of March 1982 is used.
3. For the August 1981 storm, the average groundwater table for the period 1960-1975 is input.

An additional run using daily rainfall from April 23-30, 1982, with the average highest groundwater table as the initial condition was done to evaluate the alternatives in an event with little initial groundwater storage. Daily rainfall for several stations, such as Miami International Airport and the Miami Field Station, were used. Rainfall for each node point is estimated by linear interpolation between station values. The calculated values are divided uniformly over the 24 hourly time steps. Thus, the rainfall distribution is much smoother, but less than the maximum hourly rainfall. In addition, the spatial distribution of rainfall is smoother than the actual variation due to the linear interpolation.

The initial stages, if available either from the daily water readings or from the reports of the storm events published by the S.F.W.M.D., were input. For canals with more than one downstream structure, the average stage of the downstream structures was input. If the stage was not available, the initial stage was assumed to be the minimum stage.

Results of the Model Run

1. Tables 2-5 give the simulated groundwater table, ponding depth, and head (groundwater level + ponding depth) at specified dates for various locations in the study area. The results for the present system, and the two alternatives are presented. The groundwater

table is given in ft. m.s.l., the ponding depth in feet, and the head in ft. m.s.l.

2. Contour Plots of Simulated Storms

a. April 24-25, 1979 Storm

Figures 1A-1 thru 1A-3	Groundwater table under the present system
Figures 1B-1 thru 1B-3	Groundwater table for Alternative 1
Figures 1C-1 thru 1C-3	Groundwater table for Alternative 2

b. April 23-25, 1982 Storm

Figures 2A-1 thru 2A-3	Groundwater table under the present system
Figures 2B-1 thru 2B-3	Groundwater table for Alternative 1
Figures 2C-1 thru 2C-3	Groundwater table for Alternative 2

c. August 16-20, 1981 Storm

Figures 3A-1 thru 3A-3	Groundwater table under the present system
Figures 3B-1 thru 3B-3	Groundwater table for Alternative 1
Figures 3C-1 thru 3C-3	Groundwater table for Alternative 2

d. April 23-30 rainfall with high initial groundwater table

Figures 4A-1 thru 4A-3	Groundwater table under the present system
Figures 4A-4 thru 4A-8	Ponding depth Alternative **under the present system**
Figures 4B-1 thru 4B-3	Groundwater table for Alternative 1
Figures 4B-4 thru 4B-8	Ponding depth for Alternative 1
Figures 4C-1 thru 4C-3	Groundwater table for Alternative 2
Figures 4C-4 thru 4C-8	Ponding depth for Alternative 2

IV. Summary and Conclusions

The response of the groundwater table, and the ponding depth to changes in the operation and modifications to the system, takes place at nodes at or near the canals involved. The greater the distance from the canals, the lesser the response of groundwater stage and/or ponding depth to the change. Thus, the rate of surface flow and/or groundwater seepage into the canals determines the relative efficiency of each alternative to minimize flooding.

The findings from Alternative 1 are:

A. West Miami Area

1. The groundwater level is 0.1 ft. lower than under the present system. This is evident under the storm events analyzed.
2. The average ponding depth is 0.01 ft. lower than under the present system. This can be seen in Table 5, and by comparing Figure 4B-5 with 4A-4 and Figure 4B-6 with 4A-6.

B. Along C-4 West of Coral Gables Canal

1. The ponding depth is 0.01 to 0.1 ft. greater during periods of heavy rainfall (April 23-26, 1982 and April 25-26, 1979). This can be seen in Tables 1 and 5 and by comparing Figure 4B-5 with 4A-5.
2. The groundwater table was 0.2-0.3 ft. higher the day before the heaviest rainfall as shown in the analyses of the April 1982 and August 1981 events.
3. The groundwater level after the storm event was 0.5-0.8 ft. higher than under the present system. This is the case for all storm events analyzed.

C. <u>Groundwater Levels</u>

The groundwater level along C-4 and the Coral Gables Canal, east of the structure is 0.1-0.2 ft. lower than under the present system.

The findings from Alternative 2 are:

A. The ponding depth in the West Miami area was reduced about 0.01 ft. as shown in Table 5. After the storm event, groundwater levels were 0.1-0.2 ft. lower than under the present system. (This was the case for all storm events analyzed.)

B. Along C-4 and the Coral Gables Canal, groundwater levels were 0.1-0.2 ft. lower

The conclusions drawn from the above shows that Alternative 2 would be the more efficient method. Any flood relief provided to the City of West Miami by Alternative 1 could prove to be at the expense of increased flooding in the areas adjacent to C-4 west of the secondary structure.

V. Limitations of Model Results

Information concerning each node of the model output is simply the average value for the particular 1/3 mi. x 1/3 mi. node area. Thus, the model does not include any sub-grid scale variations. For example, suppose the head (groundwater level + ponding depth) for a particular node is 6.2 ft. above m.s.l., and the land elevation input is 6.1 ft. m.s.l., the model shows the ponding depth to be 0.1 ft. for the entire node area. There may be smaller scale variations in land elevation, that is, part of the area may be 6.5 ft. above m.s.l. and part 5.7 ft. m.s.l. Thus, if the model says the head is 6.1 ft., then some of the area is dry, while the part at 5.7 ft. is pounded 0.4 ft. Moveover, there may be flooding in an area where the model says it is dry because in reality part of the land within the node area may be below the topographic values used in the node.

A more detailed analysis of the location and depth of the flooding will require additional data not presently available. It will also require a survey of management practices imposed on local drainage canals by the local water companies.

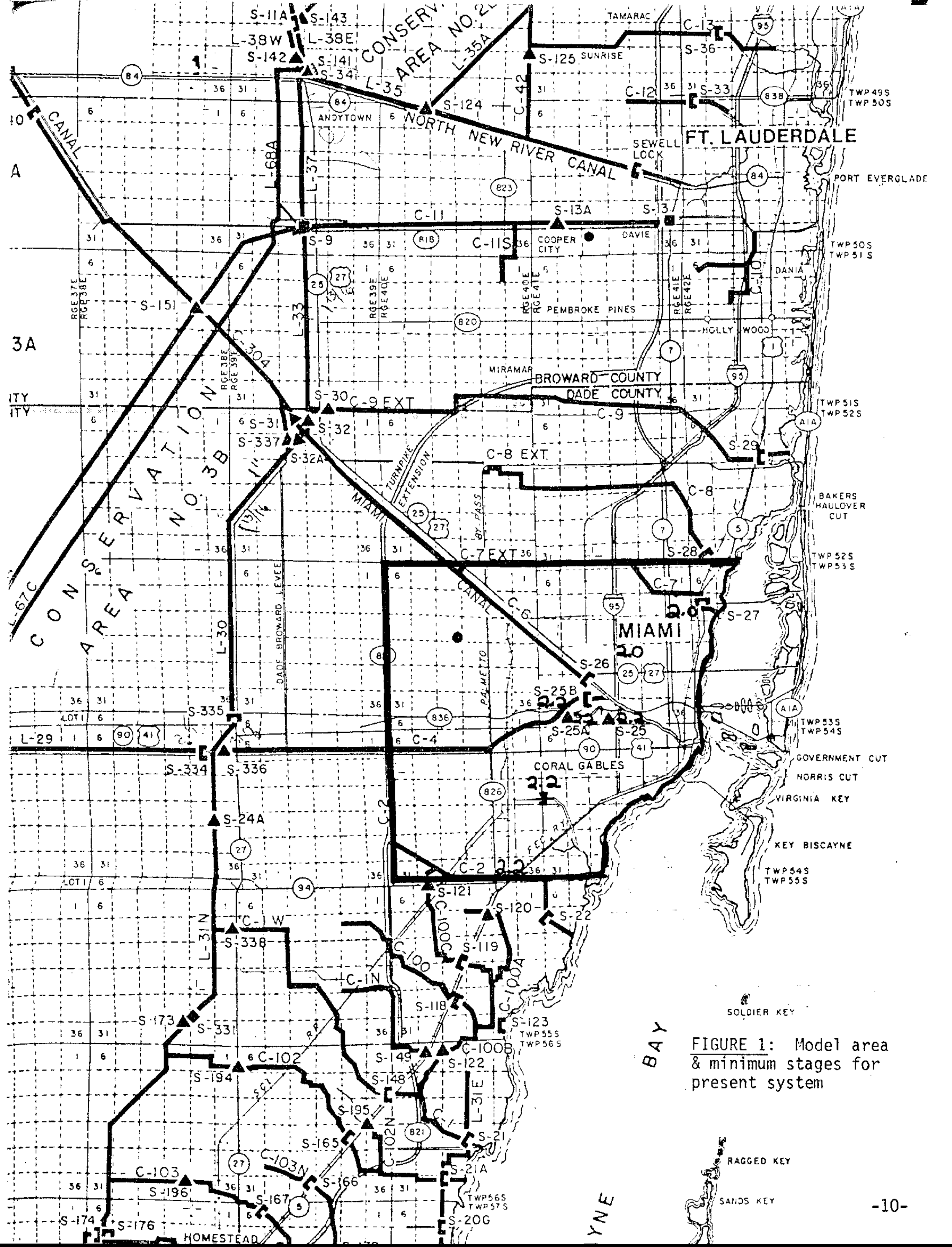


FIGURE 1: Model area & minimum stages for present system

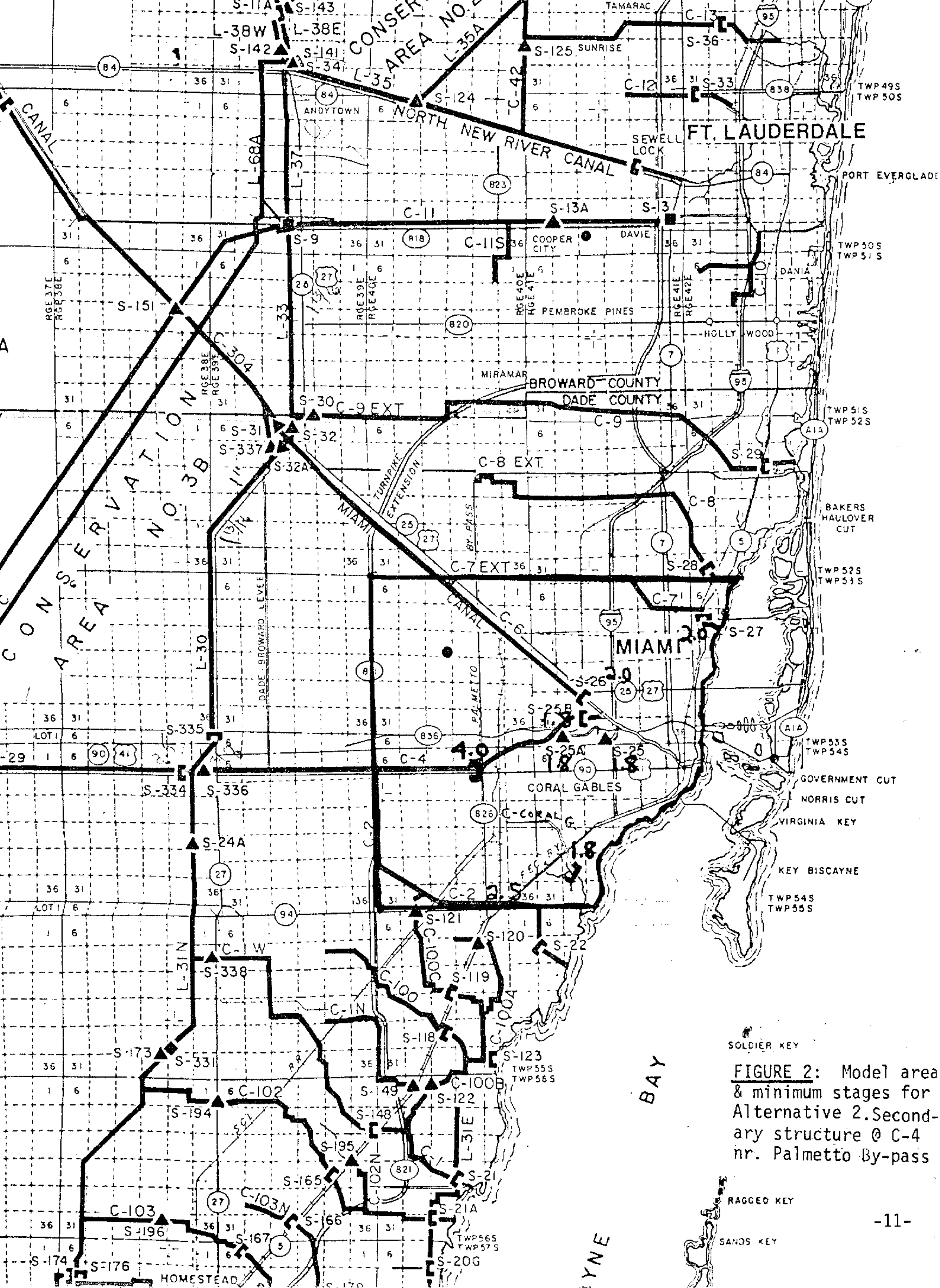


FIGURE 2: Model area & minimum stages for Alternative 2. Secondary structure @ C-4 nr. Palmetto By-pass

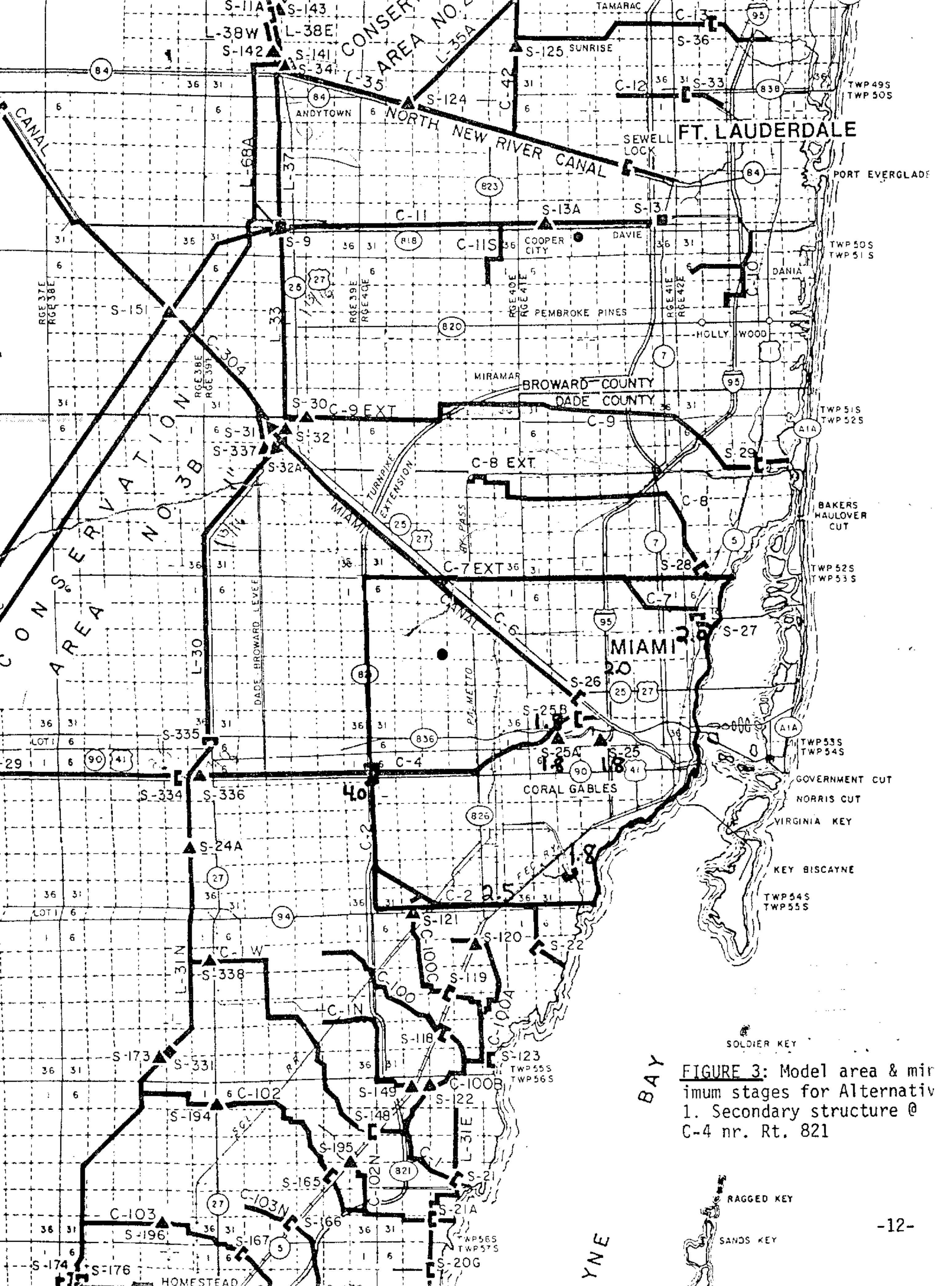


FIGURE 3: Model area & minimum stages for Alternative 1. Secondary structure @ C-4 nr. Rt. 821

TABLE 1

POTENTIAL EVAPOTRANSPIRATION DATA
(SRZ = shallow root zone, DRZ = deep root zone)

Land Use	SRZ	DRZ	PET (Annual)
1) Urban	2.0'	10.0'	20.5"
2) Agricultural	2.0'	5.0'	41.6"
3) Swamp	-0.5'	6.0'	54.3"
4) Vacant Land	3.0'	10.0'	38.4"

PET (Avg. In/Day) for Each Land Use

Month	1	2	3	4
January	.036	.072	.093	.066
February	.046	.090	.120	.085
March	.058	.118	.153	.108
April	.067	.114	.184	.130
May	.073	.149	.195	.137
June	.068	.138	.175	.124
July	.067	.139	.180	.128
August	.067	.136	.177	.127
September	.059	.120	.157	.112
October	.054	.108	.144	.100
November	.042	.085	.111	.079
December	.036	.071	.093	.066

TABLE 2

APRIL 24-25, 1979 STORM EVENT

Location	Date	Present System			Alternative 1			Alternative 2		
		G.W.	Pond	Head	G.W.	Pond	Head	G.W.	Pond	Head
City of West Miami	April 25	6.5	0.0	6.5	6.4	0.0	6.4	6.4	0.0	6.4
	April 26	6.0	0.0	6.0	5.9	0.0	5.9	5.8	0.0	5.8
	April 30	4.4	0.0	4.4	4.3	0.0	4.3	4.2	0.0	4.2
Sweetwater	April 25	6.3	0.3	6.6	6.3	0.4	6.7	6.3	0.3	6.6
	April 26	6.3	0.2	6.5	6.3	0.3	6.6	6.3	0.2	6.5
	April 30	4.3	0.0	4.3	4.7	0.0	4.7	4.2	0.0	4.2
Along C-4 nr. Coral Gables Canal	April 25	6.3	0.0	6.3	6.7	0.0	6.7	6.2	0.0	6.2
	April 26	5.3	0.0	5.3	5.6	0.0	5.6	5.2	0.0	6.2
	April 30	4.0	0.0	4.0	4.5	0.0	4.5	3.9	0.0	3.9
Along C-4 east of Coral Gables Canal	April 25	6.4	0.0	6.4	6.3	0.0	6.3	6.3	0.0	6.3
	April 26	5.4	0.0	5.4	5.2	0.0	5.2	5.2	0.0	5.2
	April 30	3.8	0.0	3.8	3.8	0.0	3.8	3.7	0.0	3.7
Along C-4 south of Miami Airport	April 25	5.3	0.0	5.3	5.3	0.0	5.3	5.3	0.0	5.3
	April 26	5.0	0.0	5.0	4.9	0.0	4.9	4.8	0.0	4.8
	April 30	4.2	0.0	4.2	3.9	0.0	3.9	3.9	0.0	3.9
Along Coral Gables Canal	April 25	5.5	0.0	5.5	5.5	0.0	5.5	5.5	0.0	5.5
	April 26	5.2	0.0	5.2	5.2	0.0	5.2	5.0	0.0	5.0
	April 30	4.1	0.0	4.1	4.0	0.0	4.0	3.9	0.0	3.9

TABLE 3

APRIL 23-26, 1982 STORM EVENT

Location	Date	Present System			Alternative 1			Alternative 2		
		G.W.	Pond	Head	G.W.	Pond	Head	G.W.	Pond	Head
City of West Miami	April 23	2.4	0.0	2.4	2.3	0.0	2.3	2.2	0.0	2.2
	April 24	4.8	0.0	4.8	4.7	0.0	4.7	4.7	0.0	4.7
	April 26	5.1	0.0	5.1	5.0	0.0	5.0	5.0	0.0	5.0
	April 30	4.4	0.0	4.0	4.3	0.0	4.3	4.3	0.0	4.3
Sweetwater	April 23	2.8	0.0	2.8	3.0	0.0	3.0	2.8	0.0	2.8
	April 24	5.4	0.0	5.4	5.7	0.0	5.7	5.3	0.0	5.3
	April 26	5.2	0.0	5.2	5.6	0.0	5.6	5.1	0.0	5.1
	April 30	4.1	0.0	4.1	4.6	0.0	4.6	4.0	0.0	4.0
Along C-4 nr. Coral Gables Canal	April 23	2.5	0.0	2.5	2.7	0.0	2.7	2.4	0.0	2.4
	April 24	4.7	0.0	4.7	5.2	0.0	5.2	4.5	0.0	4.5
	April 26	4.6	0.0	4.6	5.2	0.0	5.2	4.4	0.0	4.4
	April 30	3.9	0.0	3.9	4.7	0.0	4.7	3.7	0.0	3.7
Along C-4 east of Coral Gables Canal	April 23	2.1	0.0	2.1	2.0	0.0	2.0	2.0	0.0	2.0
	April 24	4.4	0.0	4.4	4.2	0.0	4.2	4.2	0.0	4.2
	April 26	4.3	0.0	4.3	4.2	0.0	4.2	4.1	0.0	4.1
	April 30	3.7	0.0	3.7	3.5	0.0	3.5	3.4	0.0	3.4
Along C-4 south of Miami Airport	April 23	1.5	0.0	1.5	1.4	0.0	1.4	1.4	0.0	1.4
	April 24	3.8	0.0	3.8	3.7	0.0	3.7	3.7	0.0	3.7
	April 26	3.9	0.0	3.9	3.6	0.0	3.6	3.7	0.0	3.7
	April 30	3.5	0.0	3.5	3.2	0.0	3.2	3.3	0.0	3.3
Along Coral Gables Canal	April 23	2.5	0.0	2.5	2.4	0.0	2.4	2.4	0.0	2.4
	April 24	4.6	0.0	4.6	4.5	0.0	4.5	4.5	0.0	4.5
	April 26	4.6	0.0	4.6	4.5	0.0	4.5	4.4	0.0	4.4
	April 30	4.1	0.0	4.1	4.0	0.0	4.0	3.8	0.0	3.8

TABLE 4

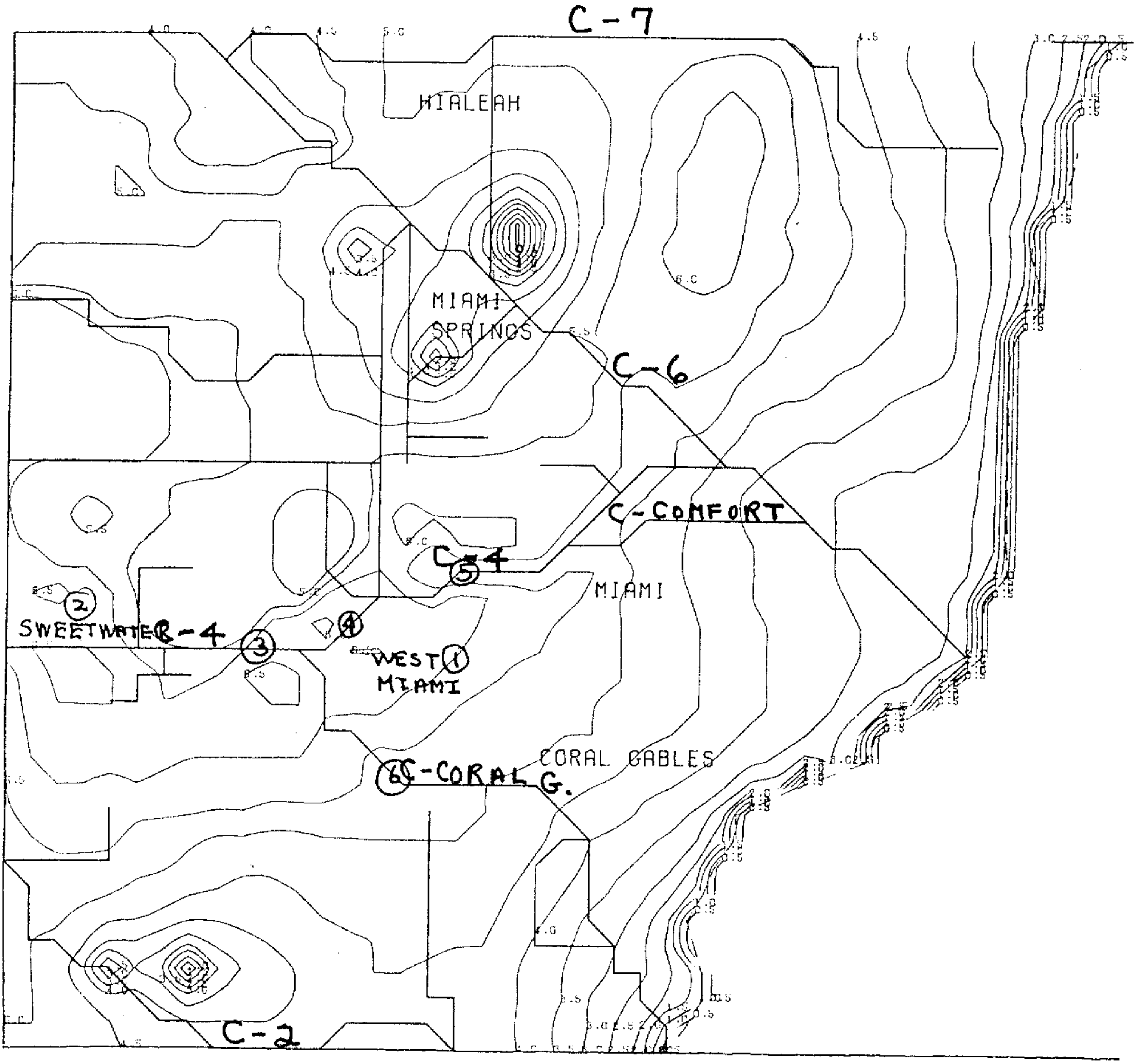
AUGUST 16-20, 1981 STORM EVENT

Location	Date	Present System			Alternative 1			Alternative 2		
		G.W.	Pond	Head	G.W.	Pond	Head	G.W.	Pond	Head
City of West Miami	August 17	4.3	0.0	4.3	4.2	0.0	4.2	4.2	0.0	4.2
	August 18	6.0	0.0	6.0	5.9	0.0	5.9	5.9	0.0	5.9
	August 22	5.4	0.0	5.4	5.3	0.0	5.3	5.3	0.0	5.3
Sweetwater	August 17	4.5	0.0	4.5	4.8	0.0	4.8	4.5	0.0	4.5
	August 18	6.3	0.4	6.7	6.3	0.5	6.8	6.3	0.4	6.7
	August 22	5.0	0.0	5.0	5.6	0.0	5.6	5.0	0.0	5.0
Along C-4 nr. Coral Gables Canal	August 17	4.0	0.0	4.0	4.5	0.0	4.5	3.8	0.0	3.8
	August 18	5.7	0.0	5.7	6.2	0.0	6.2	5.3	0.0	5.3
	August 22	4.7	0.0	4.7	4.5	0.0	4.5	4.4	0.0	4.4
Along C-4 east of Coral Gables Canal	August 17	3.8	0.0	3.8	3.8	0.0	3.8	3.8	0.0	3.8
	August 18	5.5	0.0	5.5	5.5	0.0	5.5	5.3	0.0	5.3
	August 22	4.5	0.0	4.5	4.4	0.0	4.4	4.4	0.0	4.4
Along C-4 south of Miami Airport	August 17	3.9	0.0	3.9	3.8	0.0	3.8	3.8	0.0	3.8
	August 18	5.3	0.0	5.3	5.0	0.0	5.0	4.9	0.0	4.9
	August 22	4.7	0.0	4.7	4.4	0.0	4.4	4.4	0.0	4.4
Along the Corgal Gales Canal	August 17	4.1	0.0	4.1	3.9	0.0	3.9	3.9	0.0	3.9
	August 18	5.7	0.0	5.7	5.7	0.0	5.7	5.6	0.0	5.6
	August 22	5.0	0.0	5.0	4.9	0.0	4.9	4.8	0.0	4.8

TABLE 5

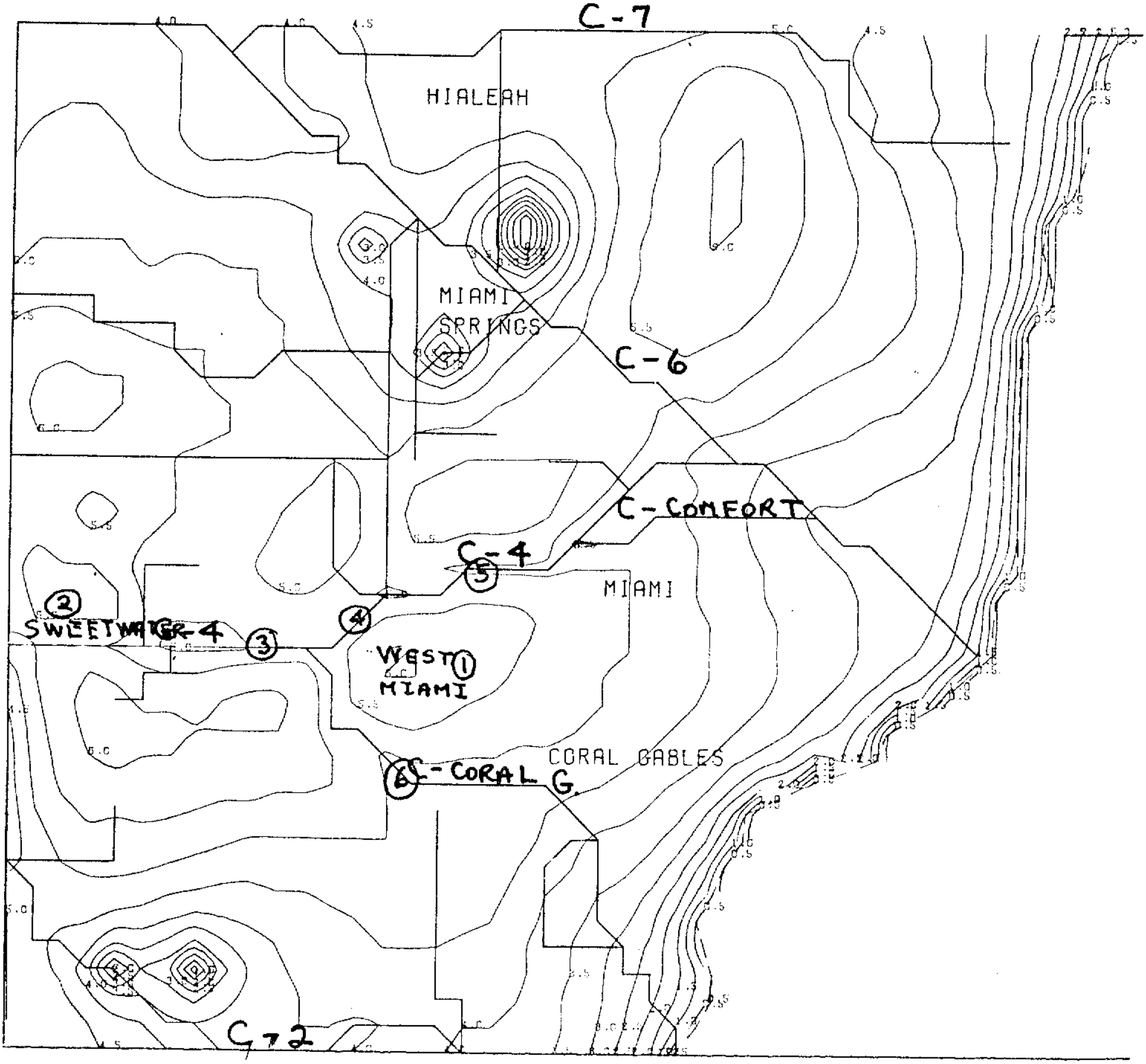
RUN USING APRIL 23-30, 1982 RAINFALL WITH AVERAGE YEARLY HIGHEST INITIAL GROUNDWATER CONDITION

Location	Date	Present System			Alternate 1			Alternate 2		
		G.W.	Pond	Head	G.W.	Pond	Head	G.W.	Pond	Head
City of West Miami	Day 2 (April 24 rainfall)	7.5	0.07	7.57	7.6	0.06	7.56	7.5	0.06	7.56
	Day 3 (April 25 rainfall)	7.5	0.01	7.51	7.5	0.01	7.51	7.5	0.01	7.51
	Day 8 (April 30 rainfall	5.5	0.0	5.5	5.3	0.0	5.3	5.3	0.0	5.3
Sweetwater	Day 2	6.3	0.5	6.8	6.3	0.6	6.9	6.3	0.5	6.8
	Day 3	6.3	0.4	6.7	6.3	0.5	6.7	6.3	0.4	6.7
	Day 8	4.6	0.0	4.6	5.1	0.0	5.1	4.5	0.0	4.5
Along C-4 nr. Coral Gables Canal	Day 2	6.2	0.0	6.2	6.7	0.01	6.71	6.1	0.0	6.1
	Day 3	5.5	0.0	5.5	6.0	0.0	6.0	5.4	0.0	5.4
	Day 8	4.3	0.0	4.3	5.0	0.0	5.0	4.2	0.0	4.2
Along C-4 east of Coral Gables Canal	Day 2	6.5	0.0	6.5	6.5	0.0	6.5	6.3	0.0	6.3
	Day 3	5.5	0.0	5.5	5.6	0.0	5.6	5.4	0.0	5.4
	Day 8	4.3	0.0	4.3	4.2	0.0	4.2	4.1	0.0	4.1
Along C-4 south of Miami Airport	Day 2	5.3	0.05	5.35	5.3	0.05	5.35	5.3	0.05	5.35
	Day 3	5.3	0.04	5.34	5.3	0.02	5.32	5.3	0.03	5.33
	Day 8	4.7	0.0	4.7	4.4	0.0	4.4	4.6	0.0	4.6
Along the Coral Gables Canal	Day 2	6.8	0.0	6.8	6.7	0.0	6.7	6.6	0.0	6.6
	Day 3	6.5	0.0	6.5	6.4	0.0	6.4	6.3	0.0	6.3
	Day 8	5.4	0.0	5.4	5.3	0.0	5.3	5.2	0.0	5.2



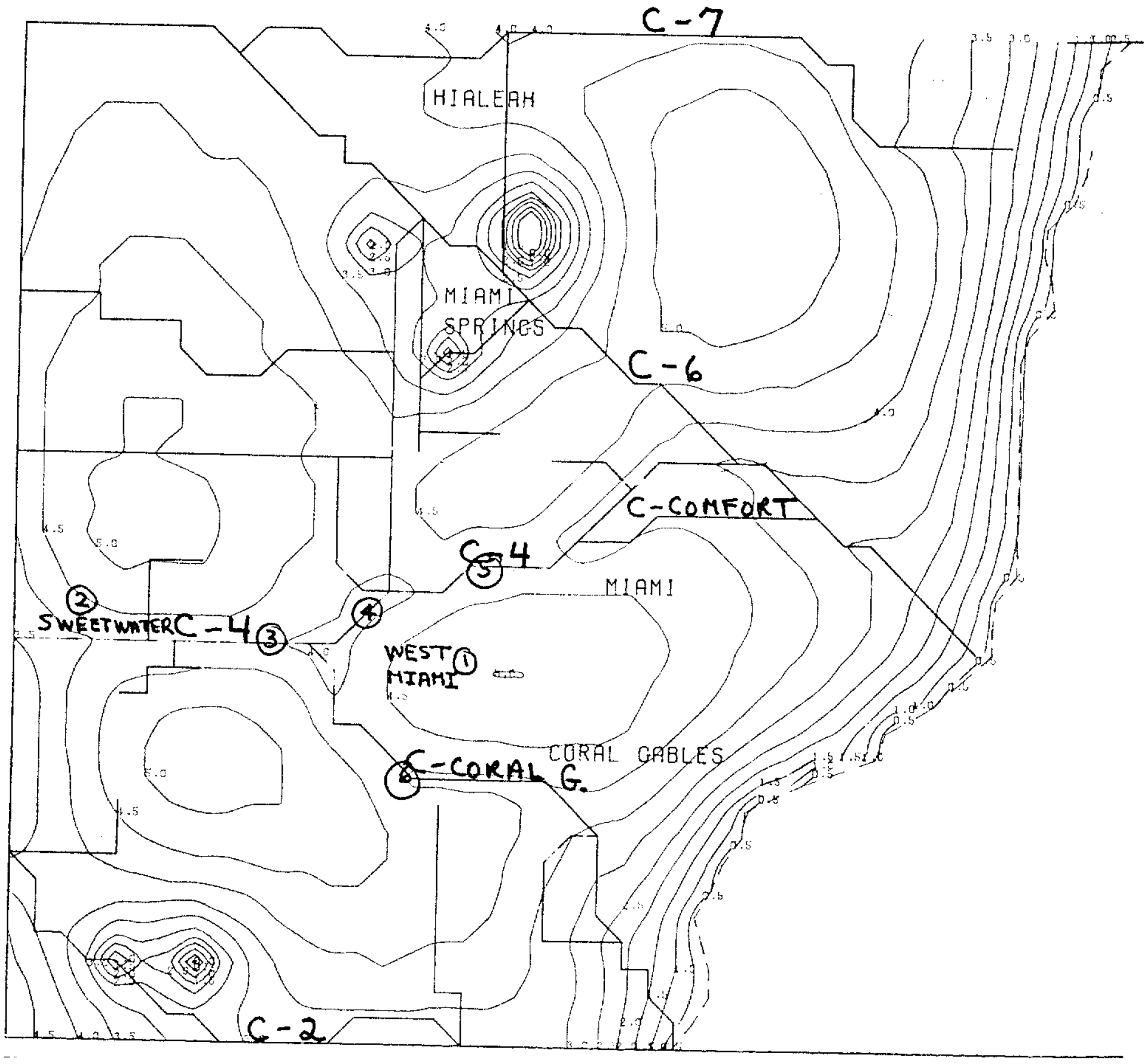
GROUNDWATER TABLE FOR END OF APRIL 25 1979 - existing structures (present system)

Figure 1A-1



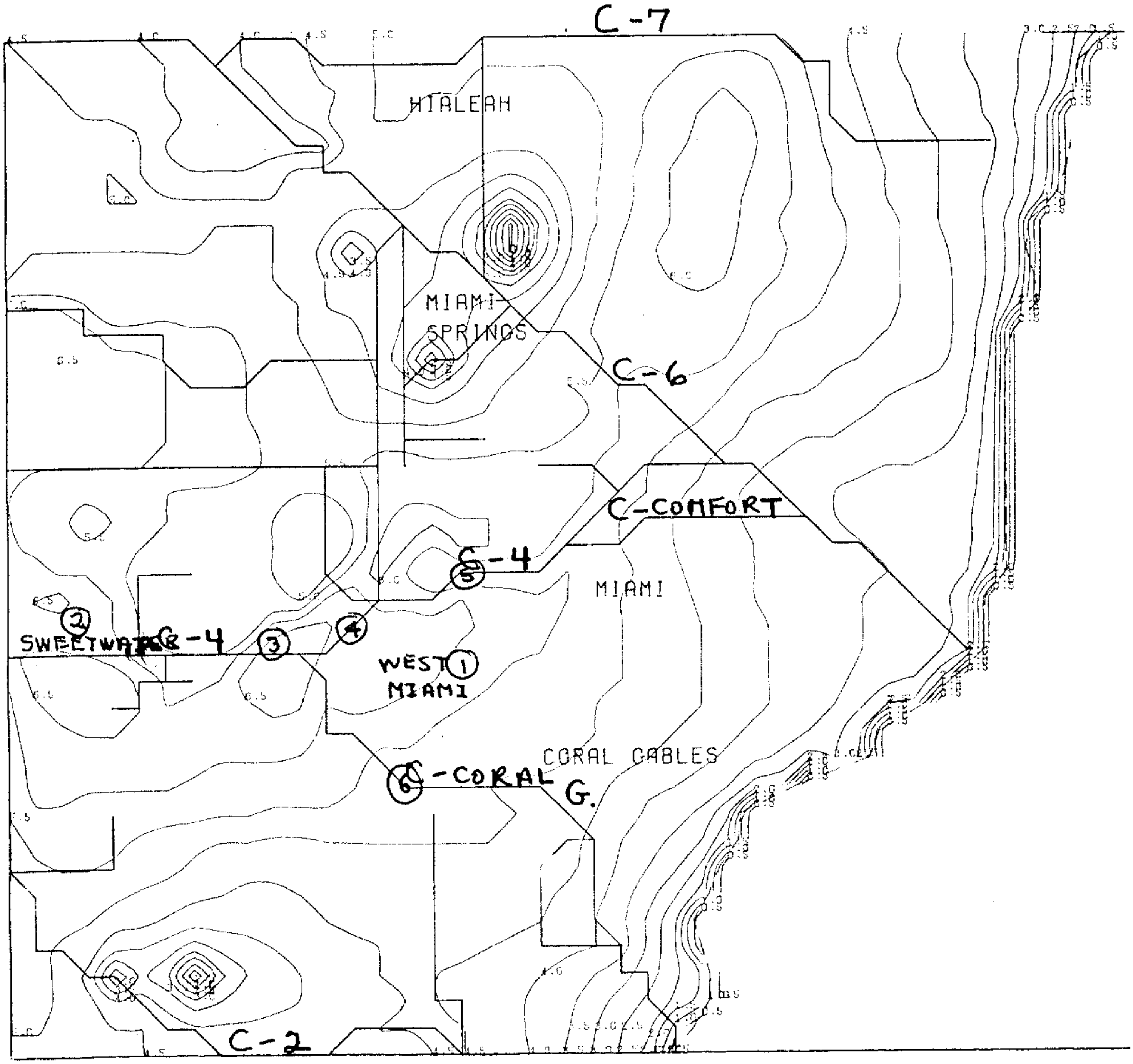
GROUNDWATER TABLE FOR END OF APRIL 26 1979 - existing structures (present system)

Figure 1A-2



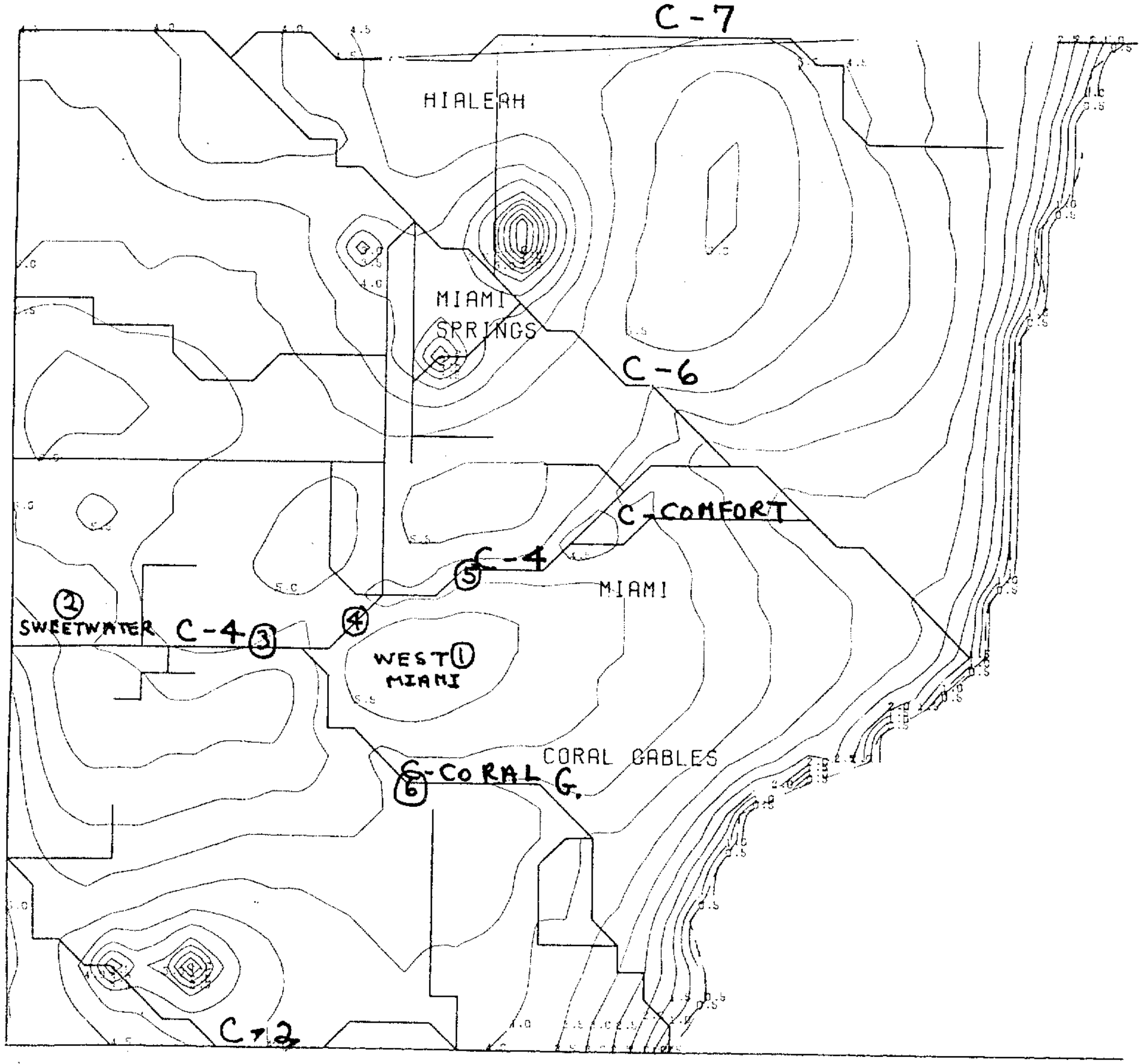
GROUNDWATER TABLE FOR END OF APRIL 30 1979 - existing structures (present system)

Figure 1A-3



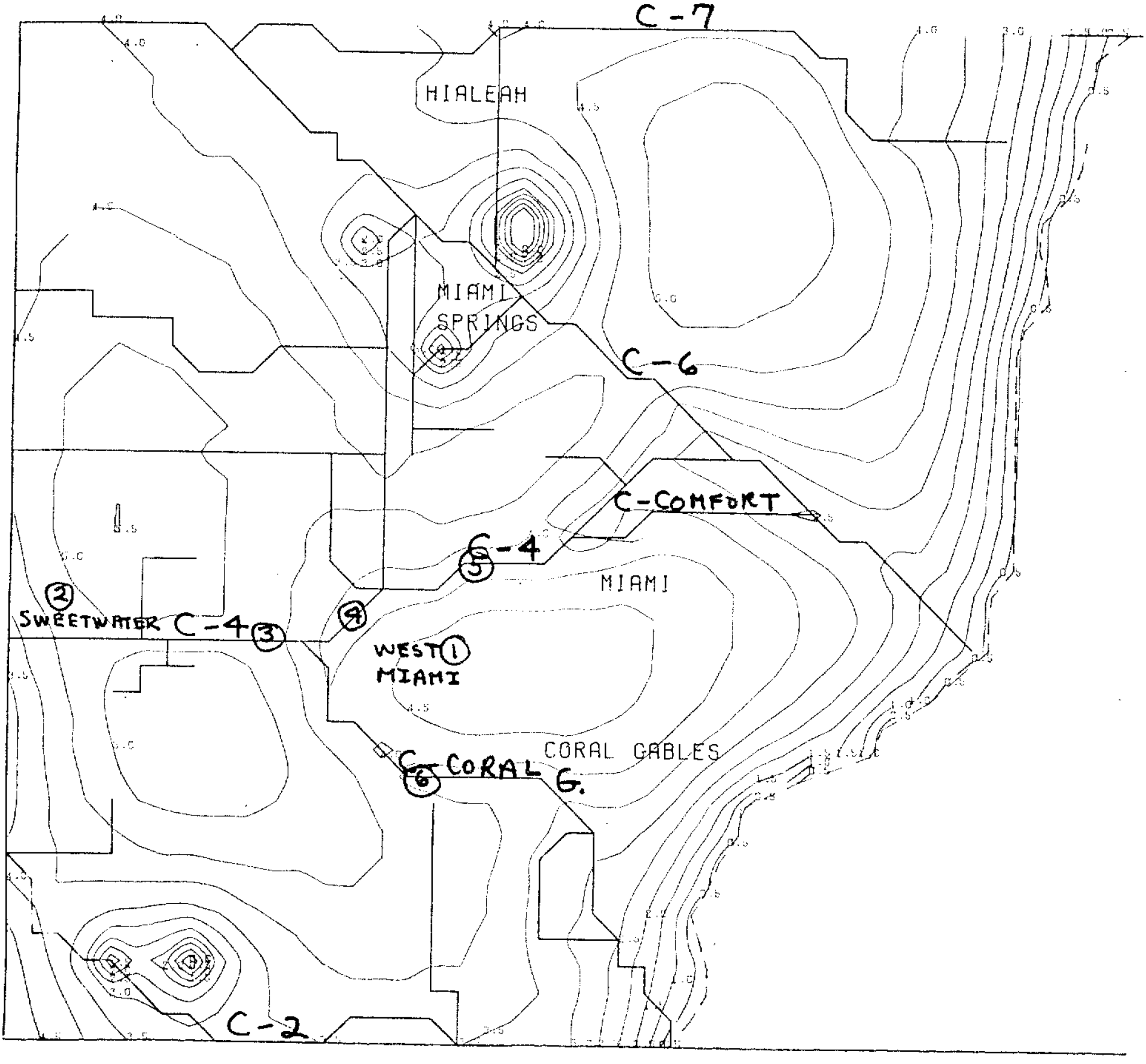
GROUNDWATER TABLE FOR END OF APRIL 25 1979 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 1B-1



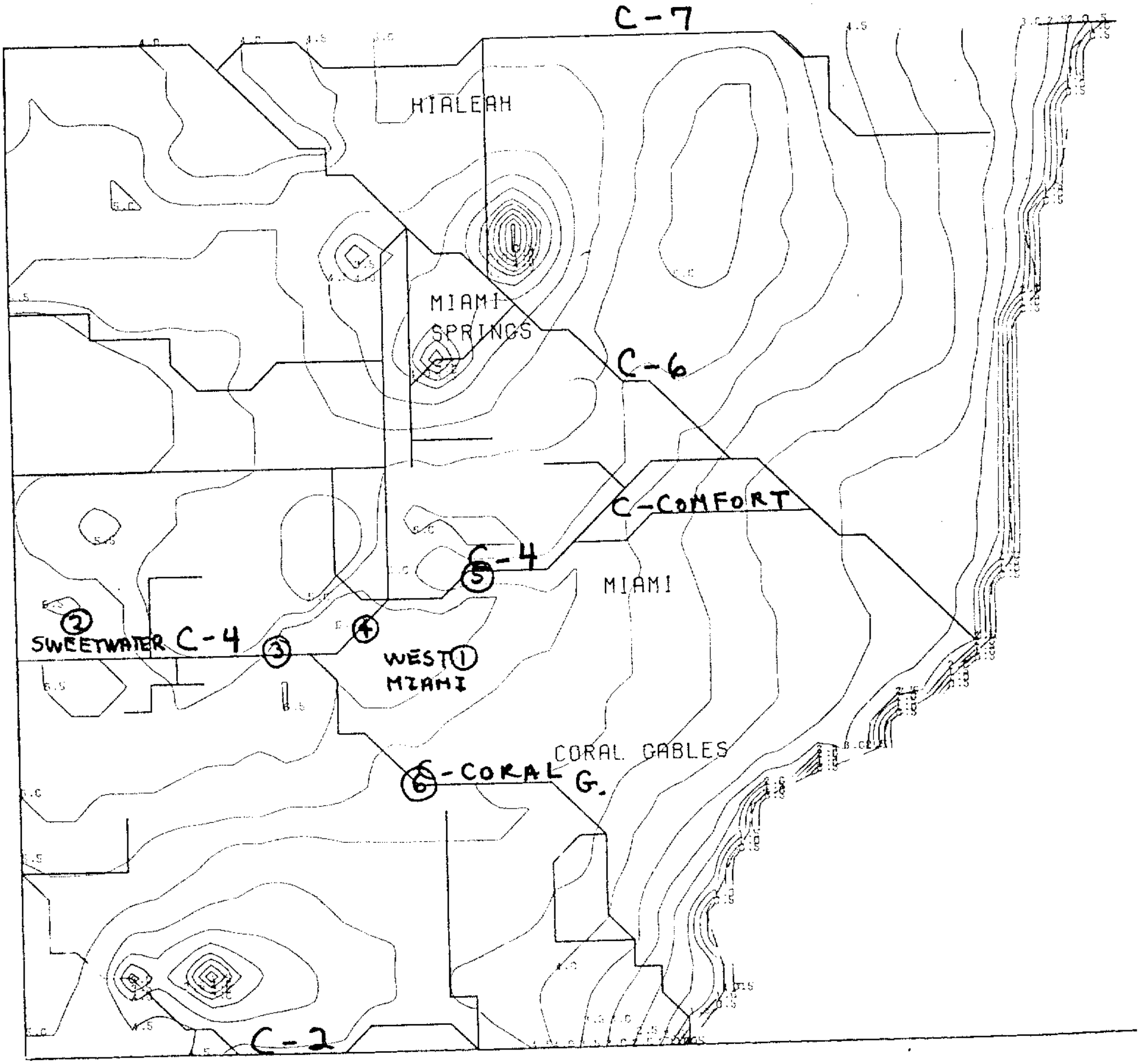
GROUNDWATER TABLE FOR END OF APRIL 26 1979 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 1B-2



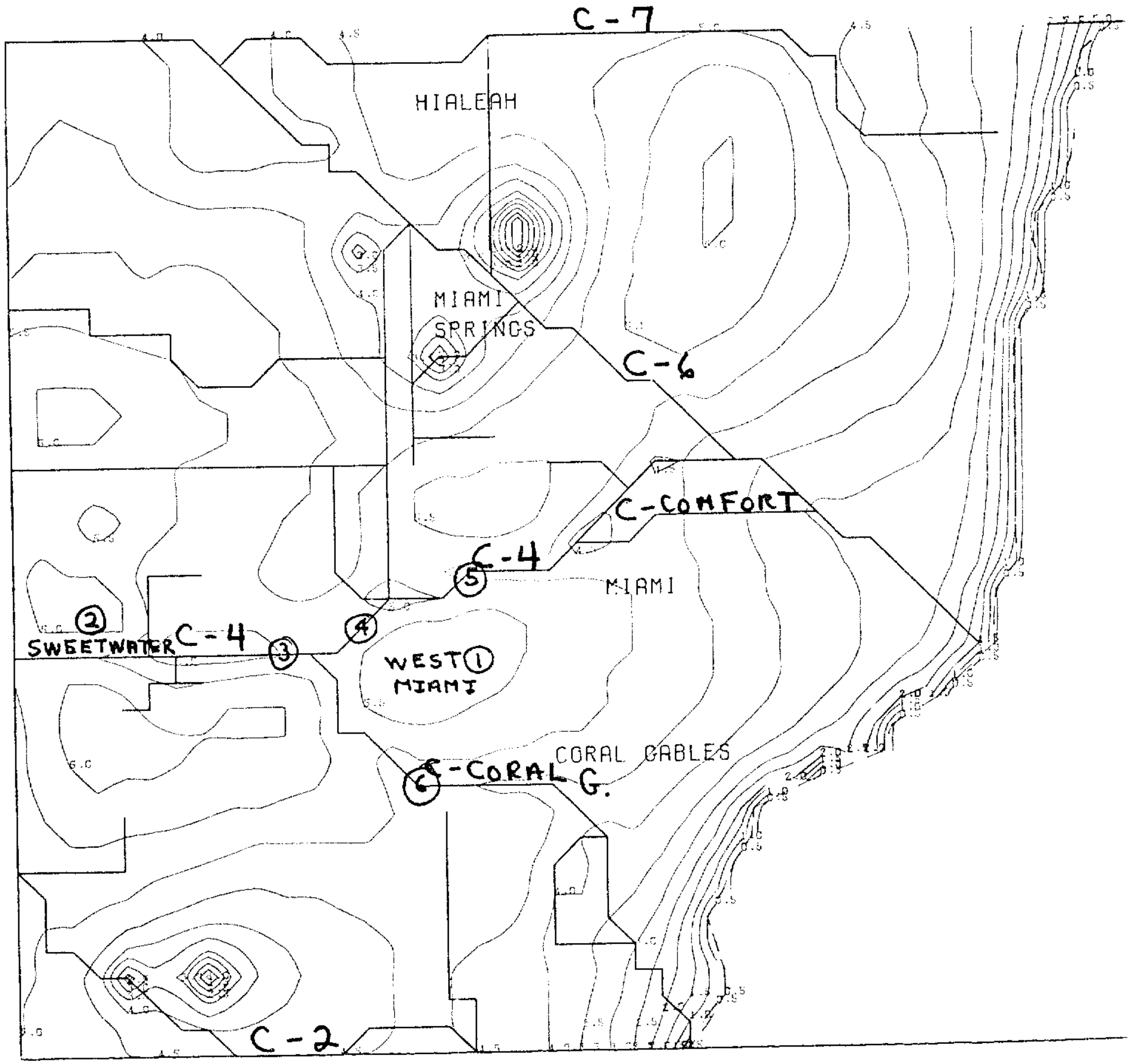
GROUNDWATER TABLE FOR END OF APRIL 30 1979 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 1B-3



GROUNDWATER TABLE FOR END OF APRIL 25 1979 - secondary structure at C-4 & C-Snapper Creek (alternative 2)

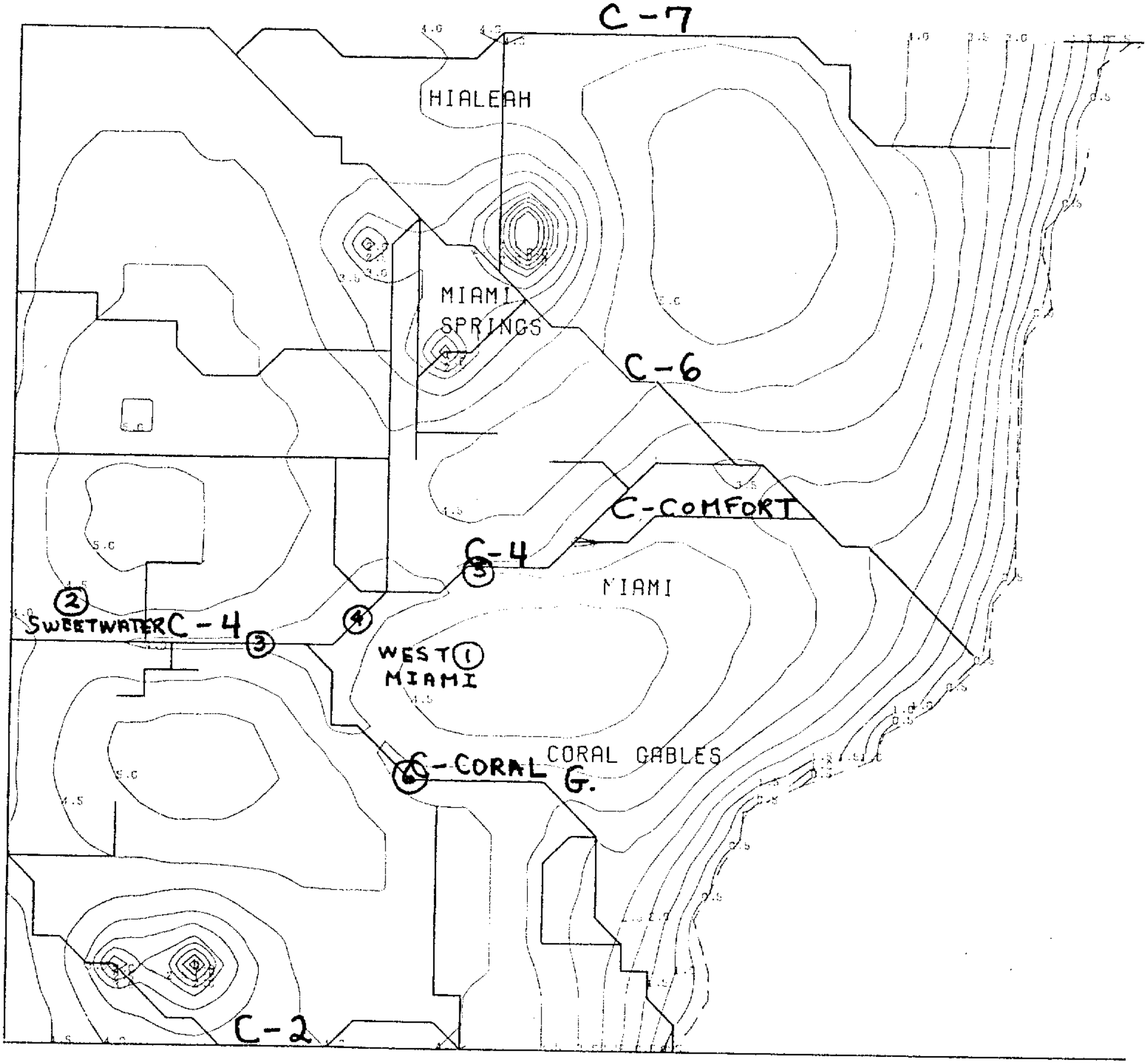
Figure 1C-1



GROUNDWATER TABLE FOR END OF APRIL 26 1979 - secondary structure at C-4 & C-Snapper Creek (Alternative 2)

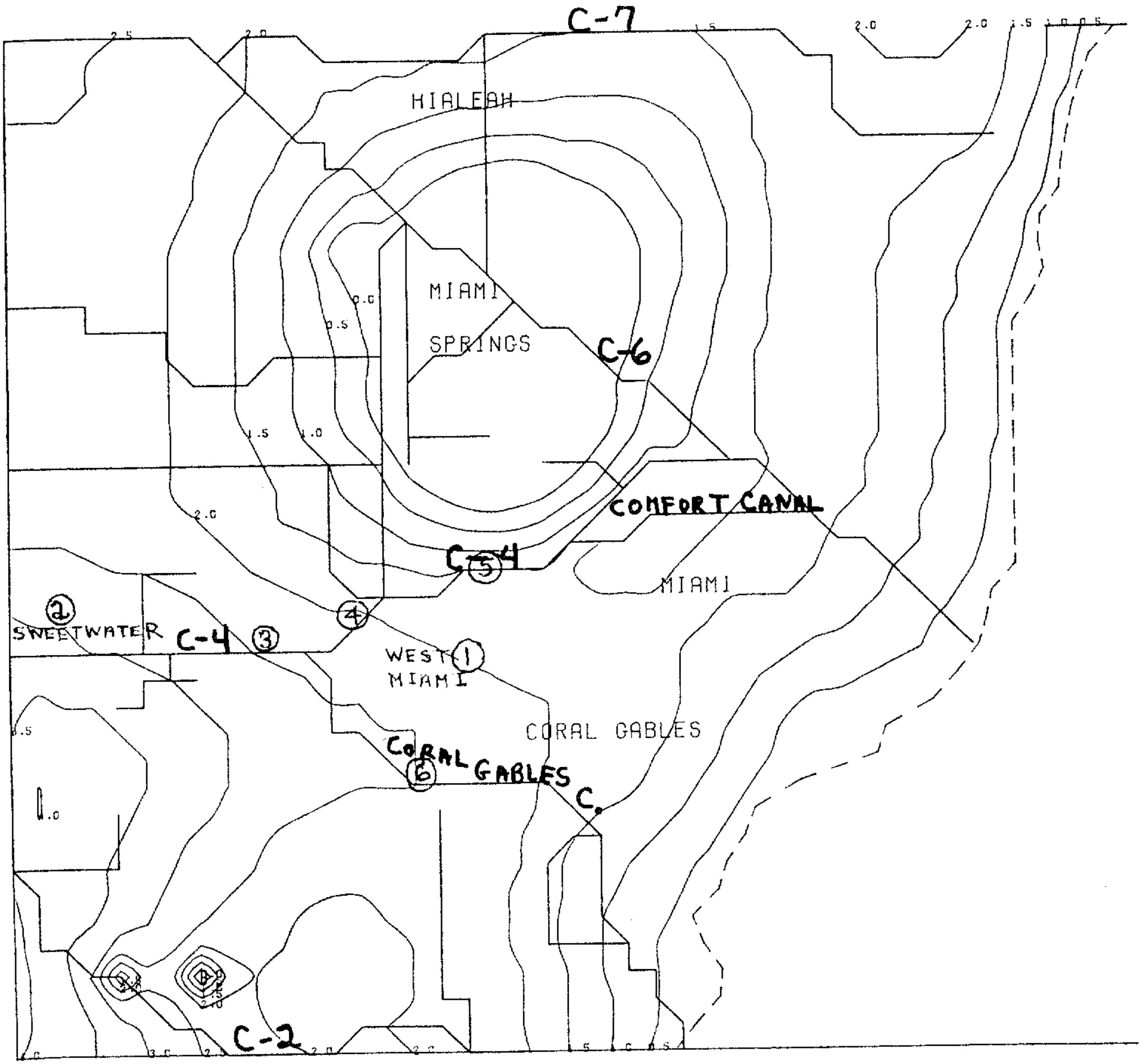
Figure 1C-2

WMD TAPENO 6145 PLOT NO 0041
USER NO RSANTEE DATE 82/06/26 TIME 01:57



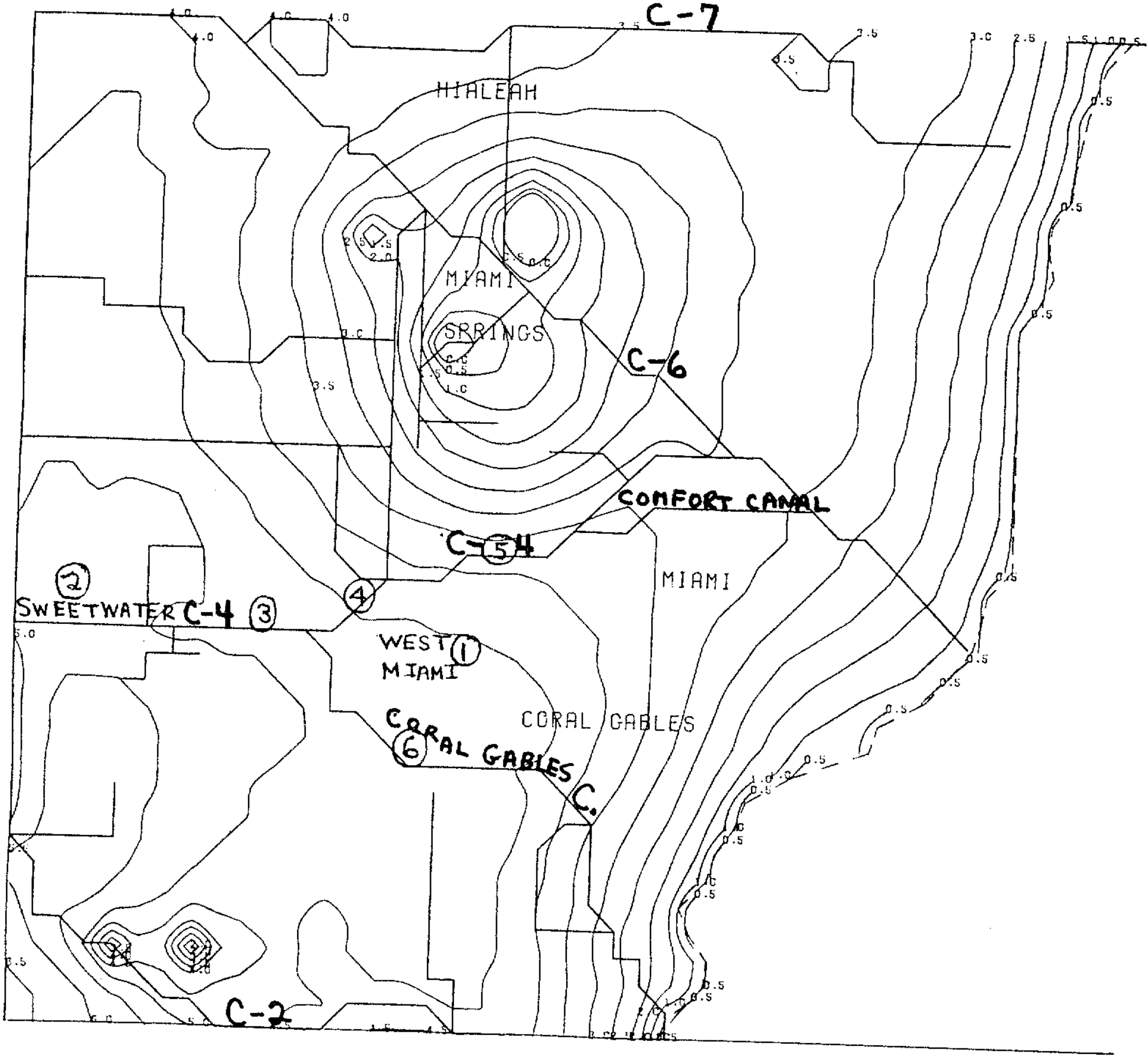
GROUNDWATER TABLE FOR END OF APRIL 30 1979 - secondary structure at C-4 & C-Snapper Creek (alternative 2)

Figure IC - 3



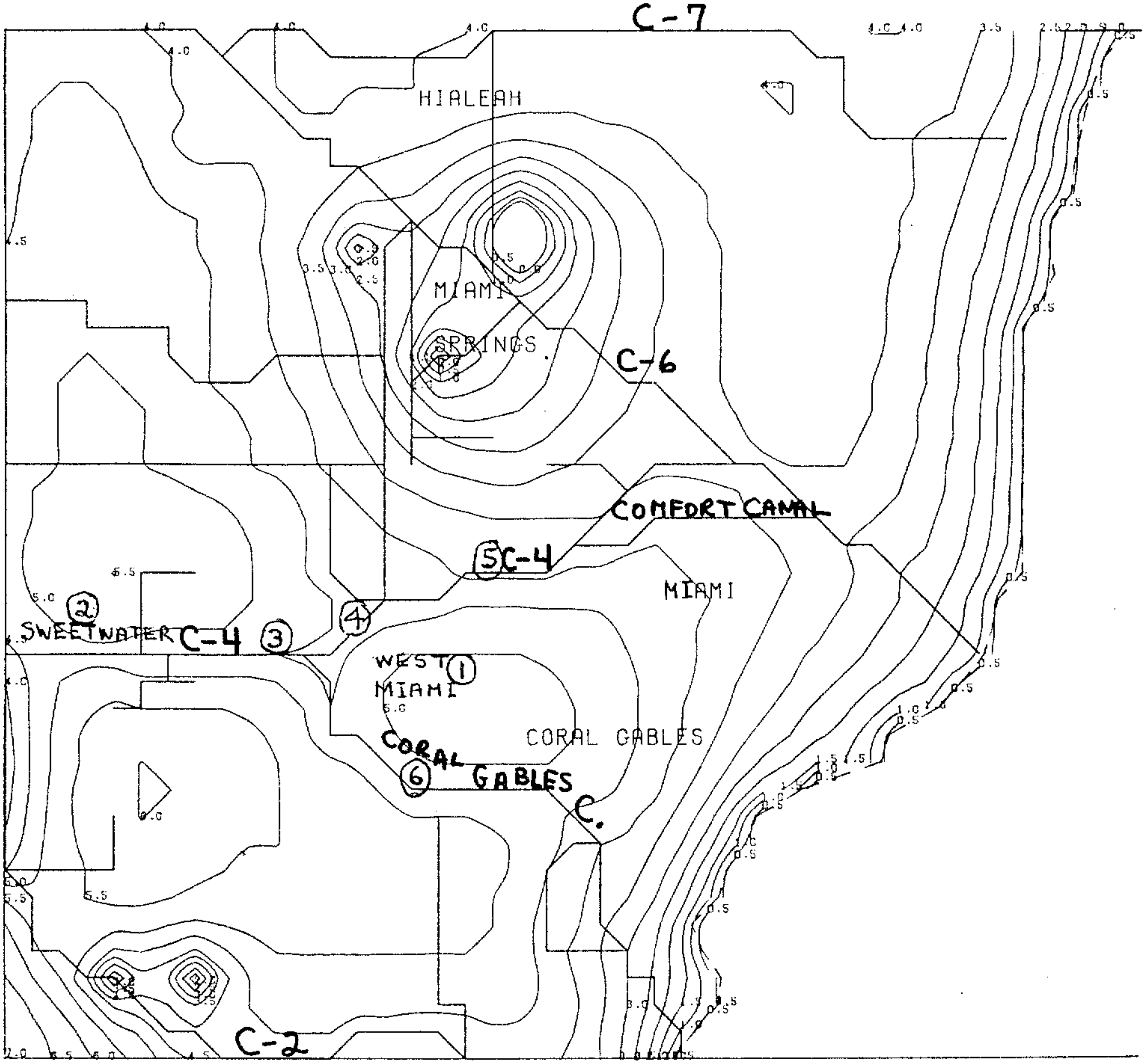
GROUNDWATER TABLE FOR END OF APRIL 23 1982

Figure 2A-1



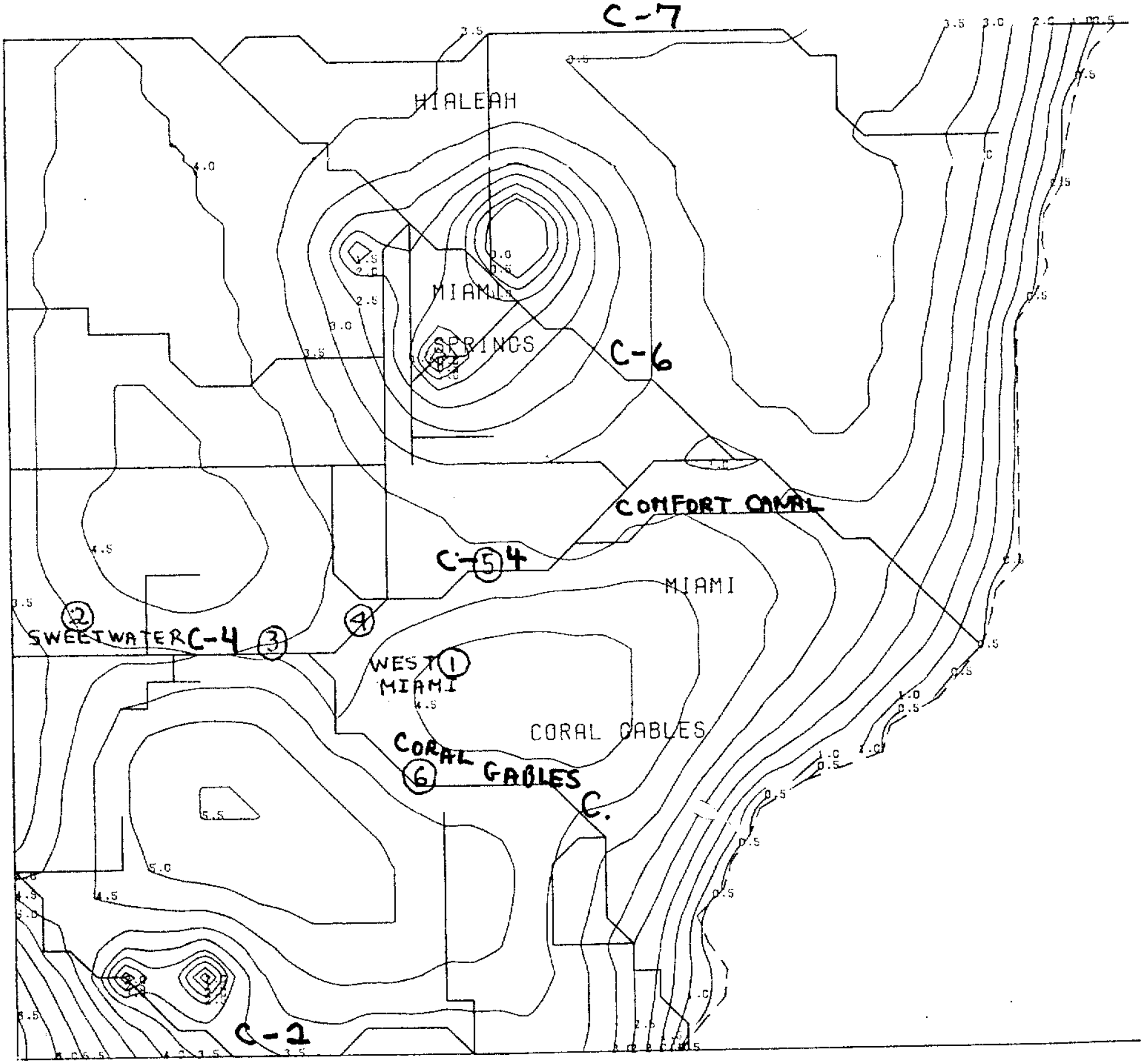
GROUNDWATER TABLE FOR END OF APRIL 24 1982

Figure 2A-2



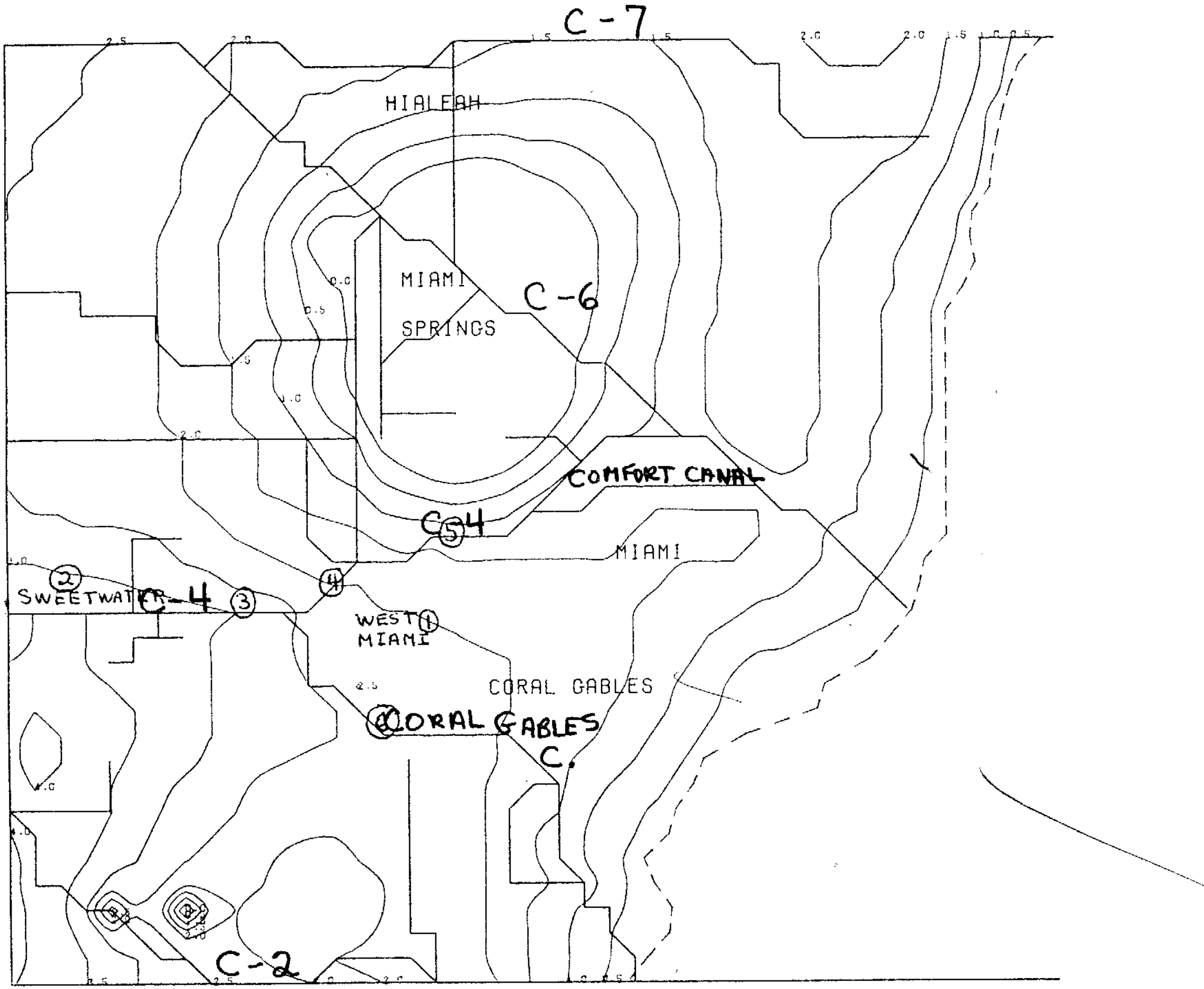
GROUNDWATER TABLE FOR END OF APRIL 26 1982

Figure 2A-3



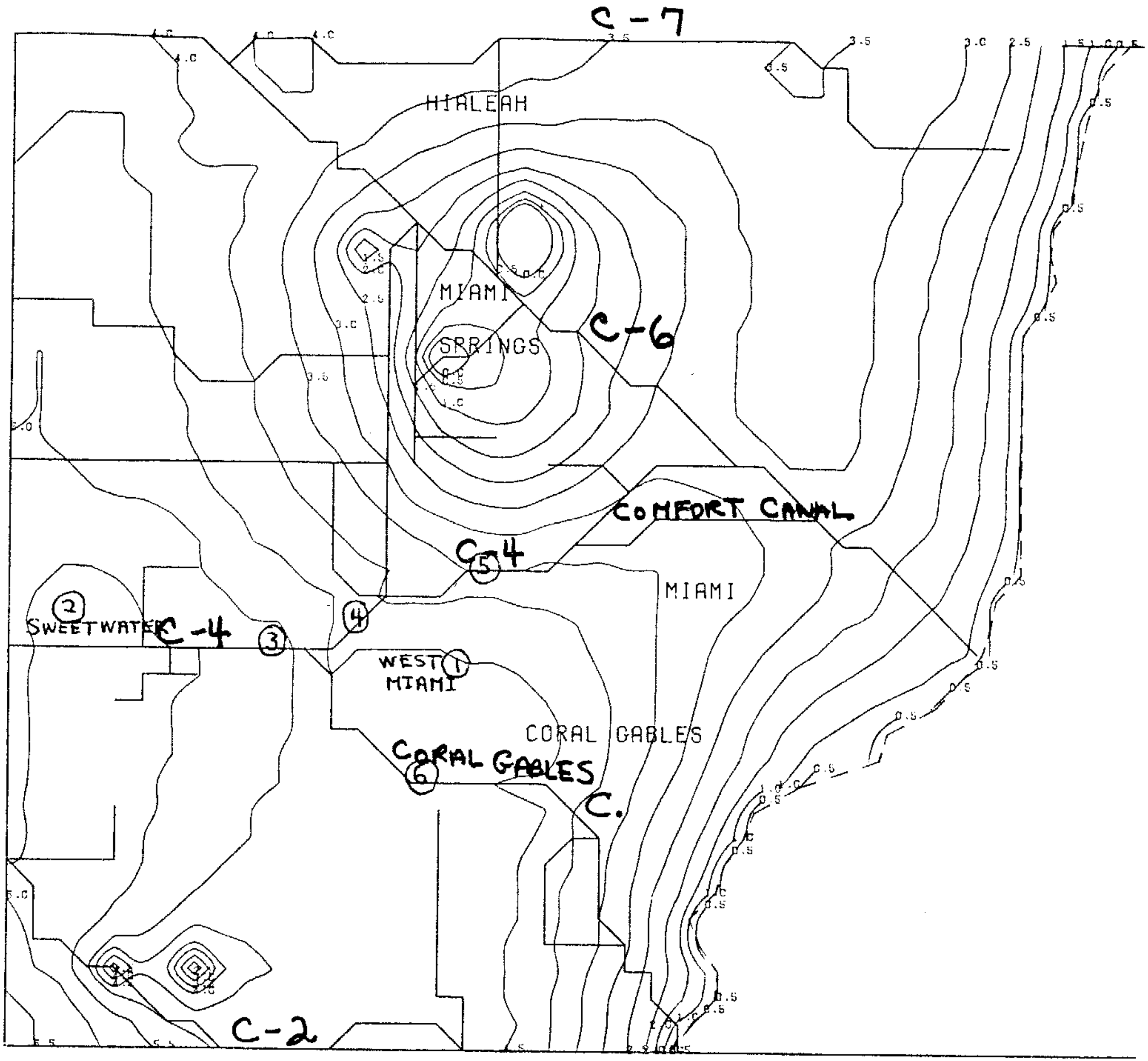
GROUNDWATER TABLE FOR END OF APRIL 30 1982

Figure 2A-4



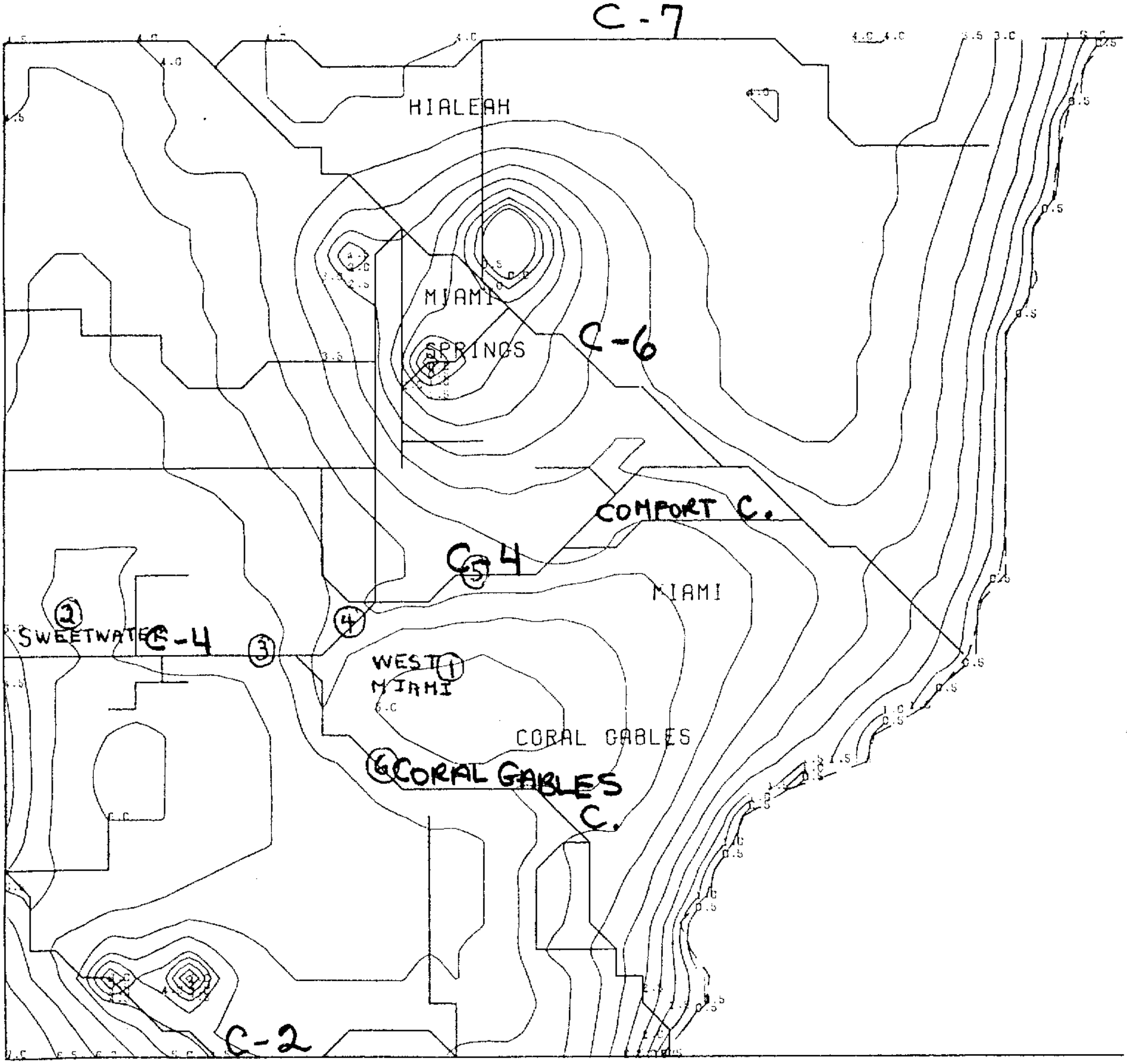
GROUNDWATER TABLE FOR END OF APRIL 23 1982

Figure 2B-1



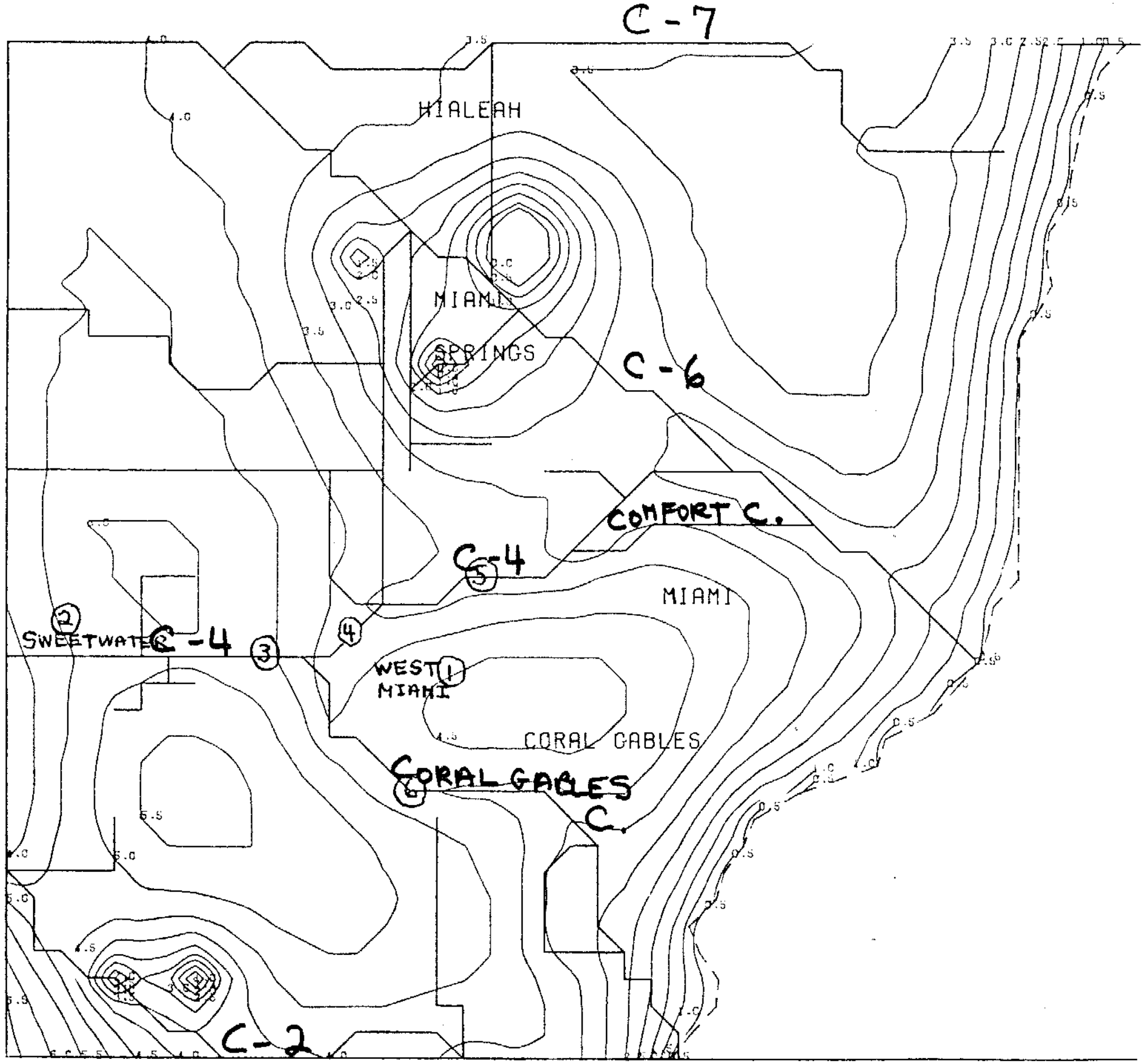
GROUNDWATER TABLE FOR END OF APRIL 24 1982

Figure 2B-2



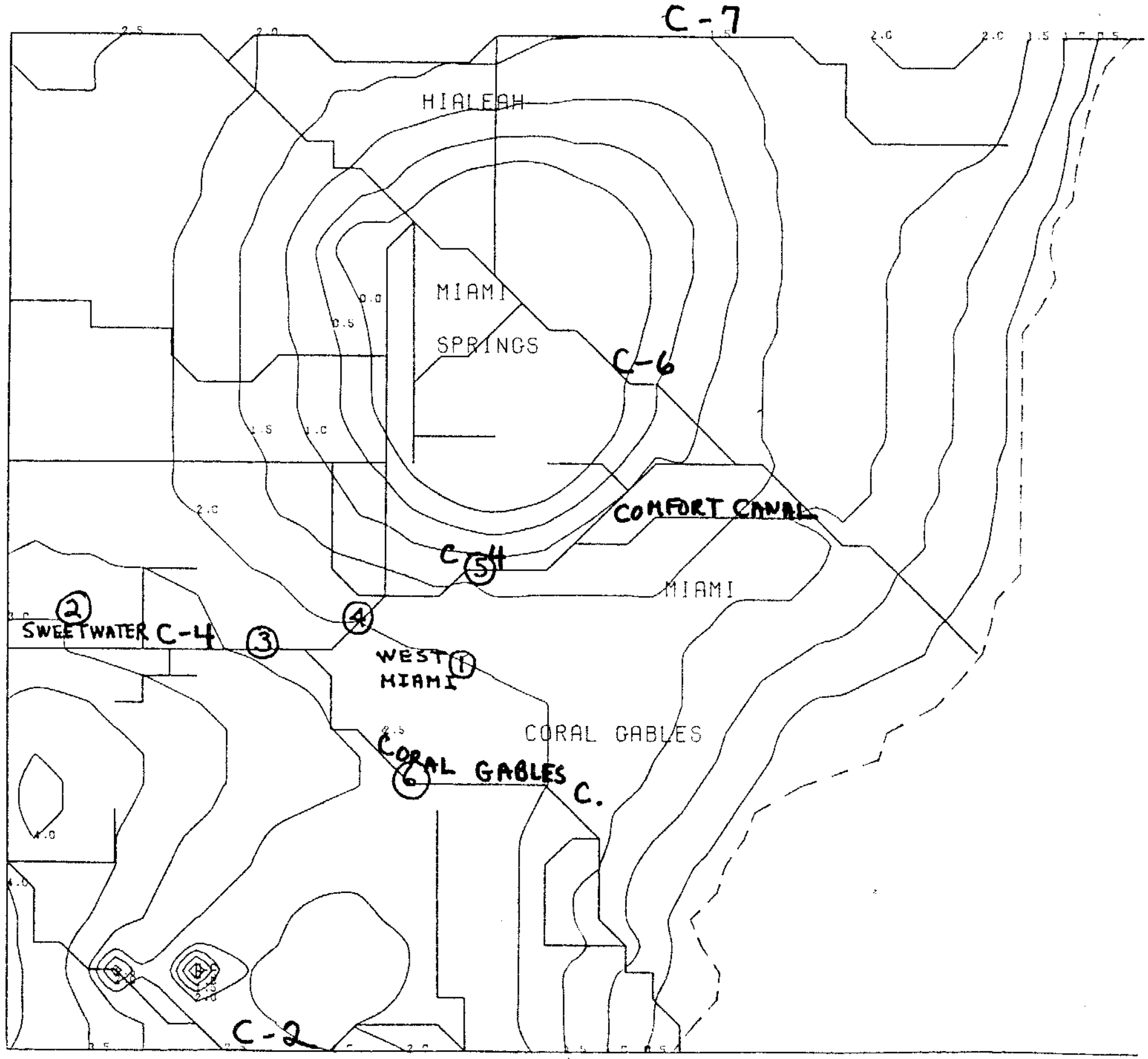
GROUNDWATER TABLE FOR END OF APRIL 26 1982

Figure 2B-3



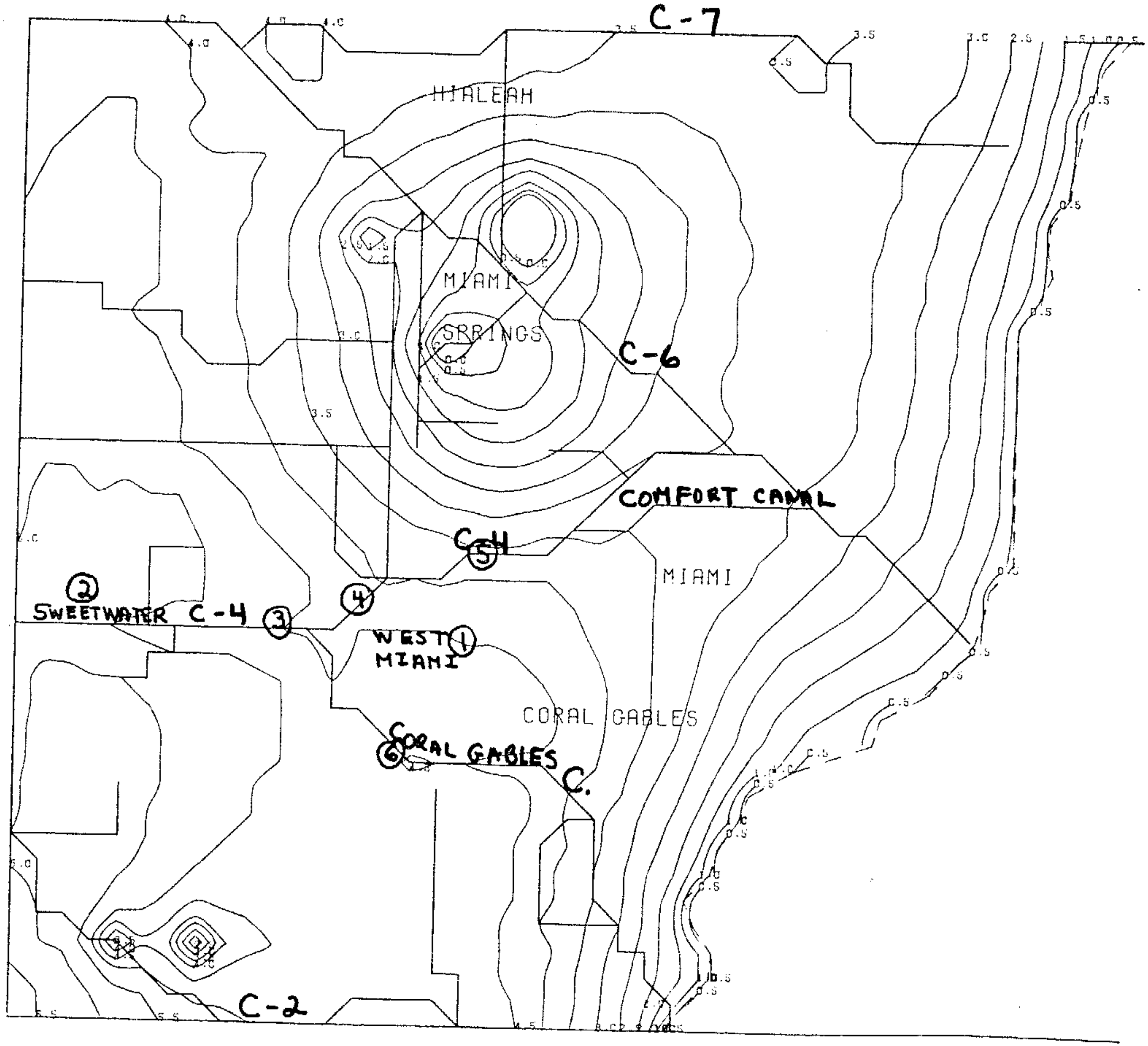
GROUNDWATER TABLE FOR END OF APRIL 30 1982

Figure 2B-4



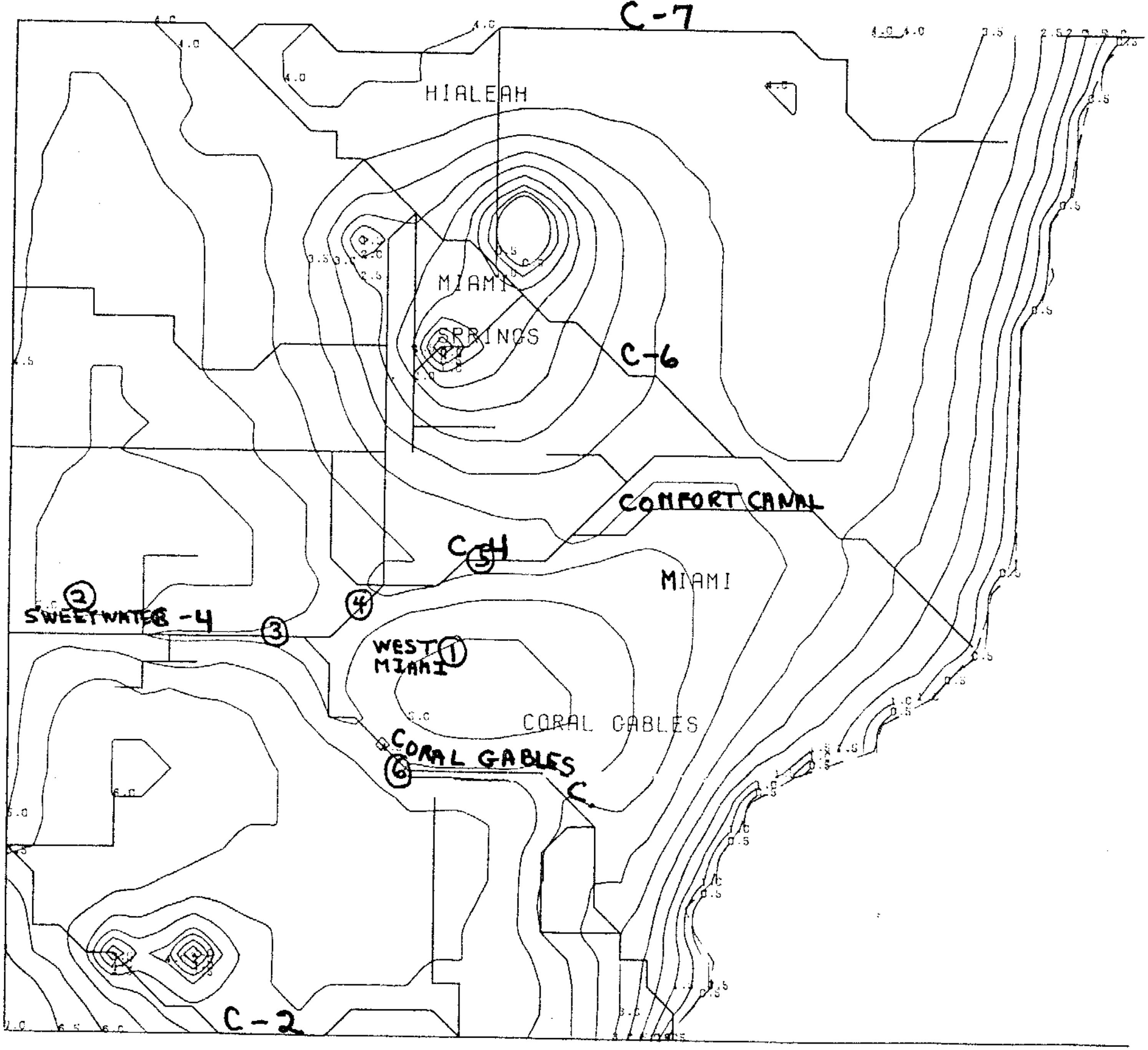
GROUNDWATER TABLE FOR END OF APRIL 23 1982

Figure 2C-1



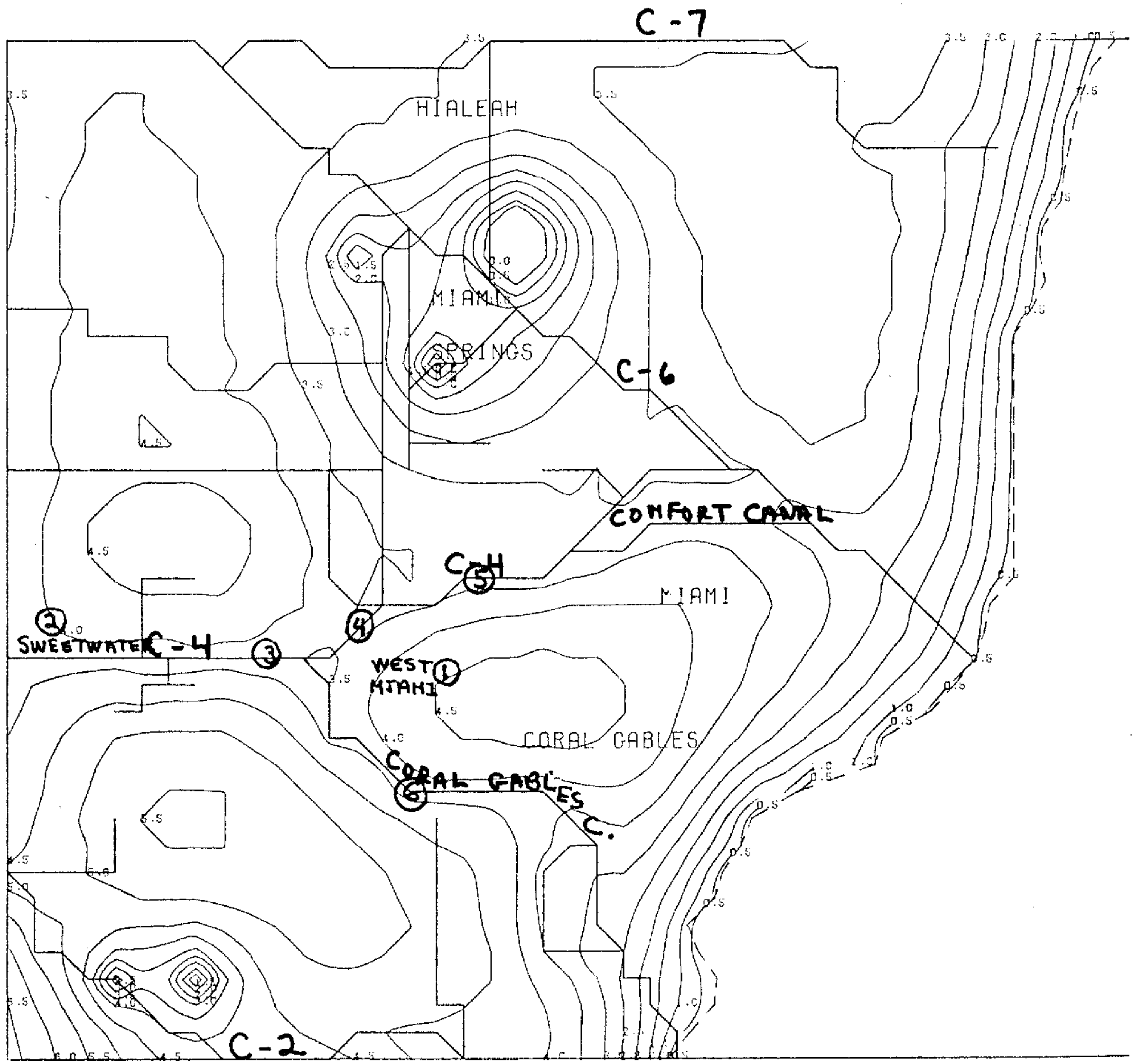
GROUNDWATER TABLE FOR END OF APRIL 24 1982

Figure 2C-2



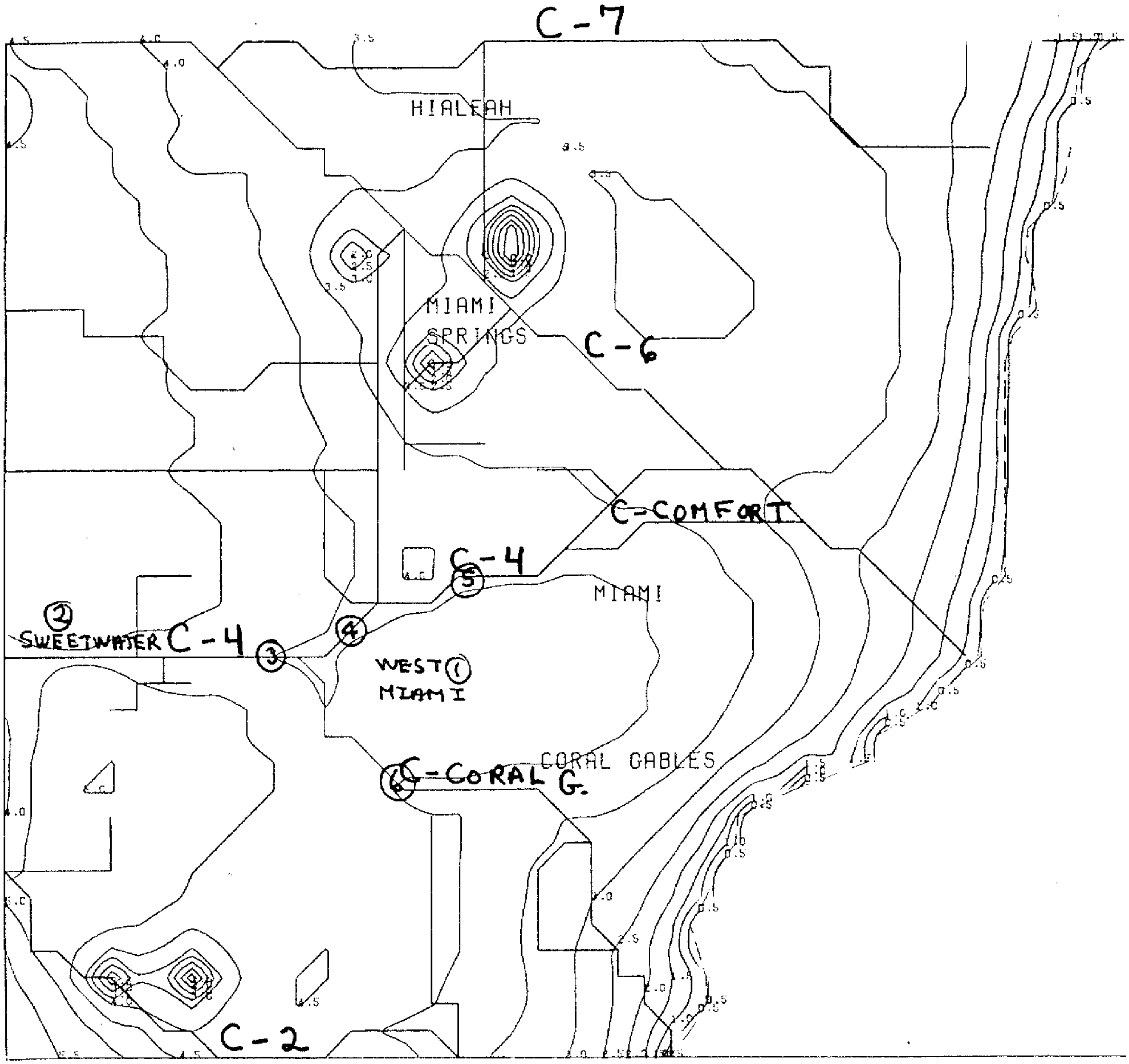
GROUNDWATER TABLE FOR END OF APRIL 26 1982

Figure 2C-3



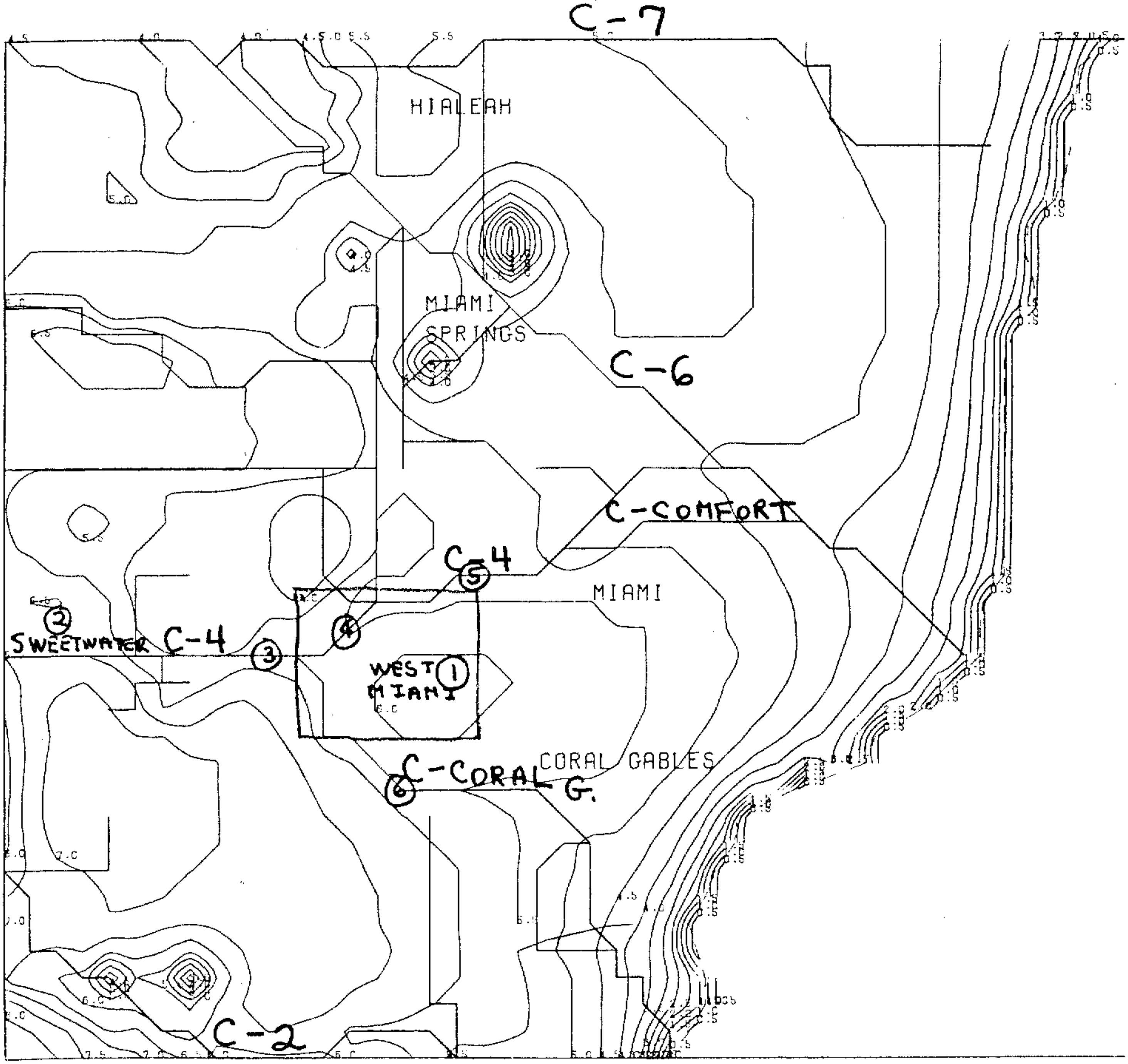
GROUNDWATER TABLE FOR END OF APRIL 30 1982

Figure 2C-4



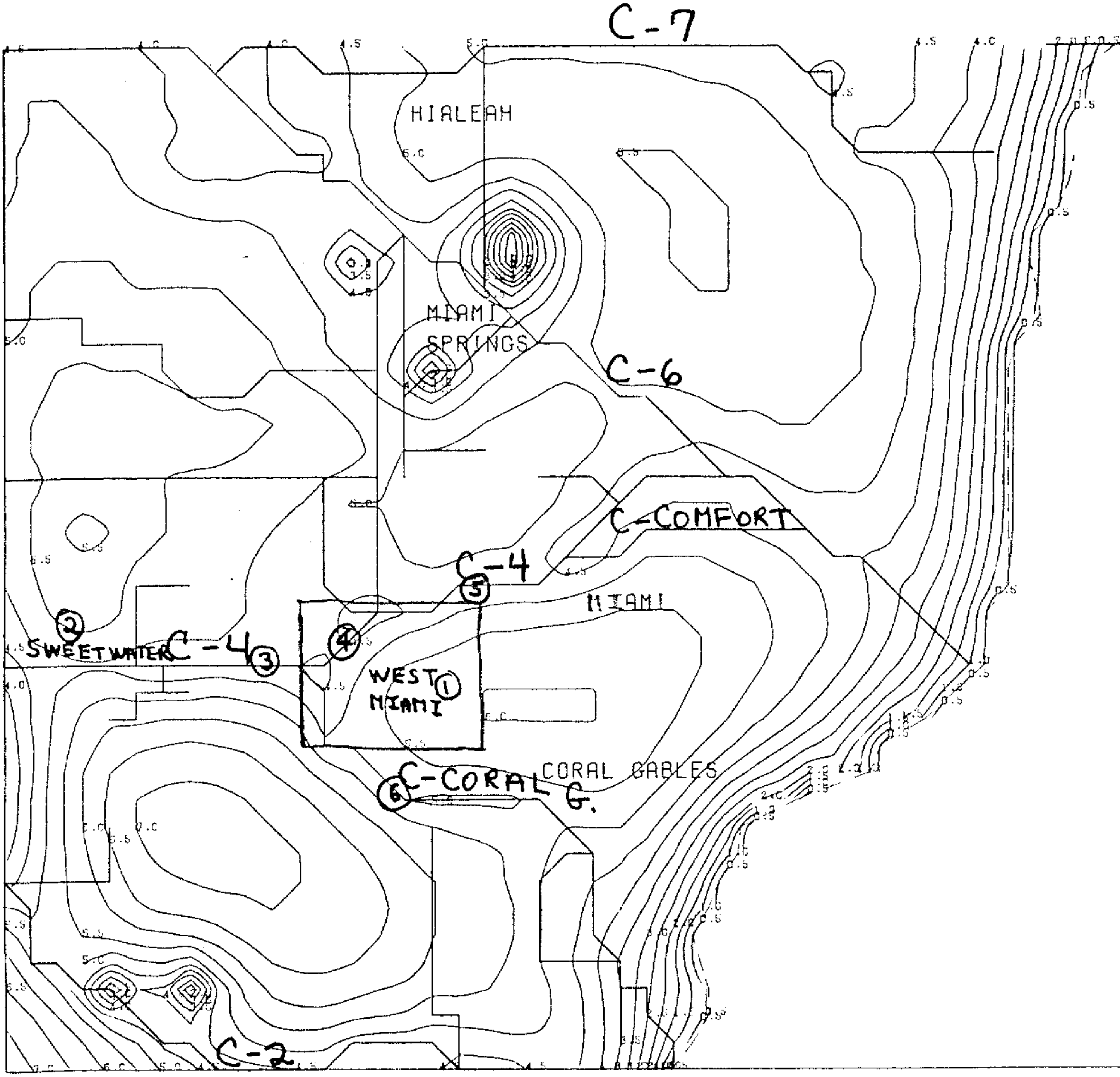
CROUNDWATER TABLE FOR END OF AUGUST 17 1981 - existing structures

Figure 3A-1



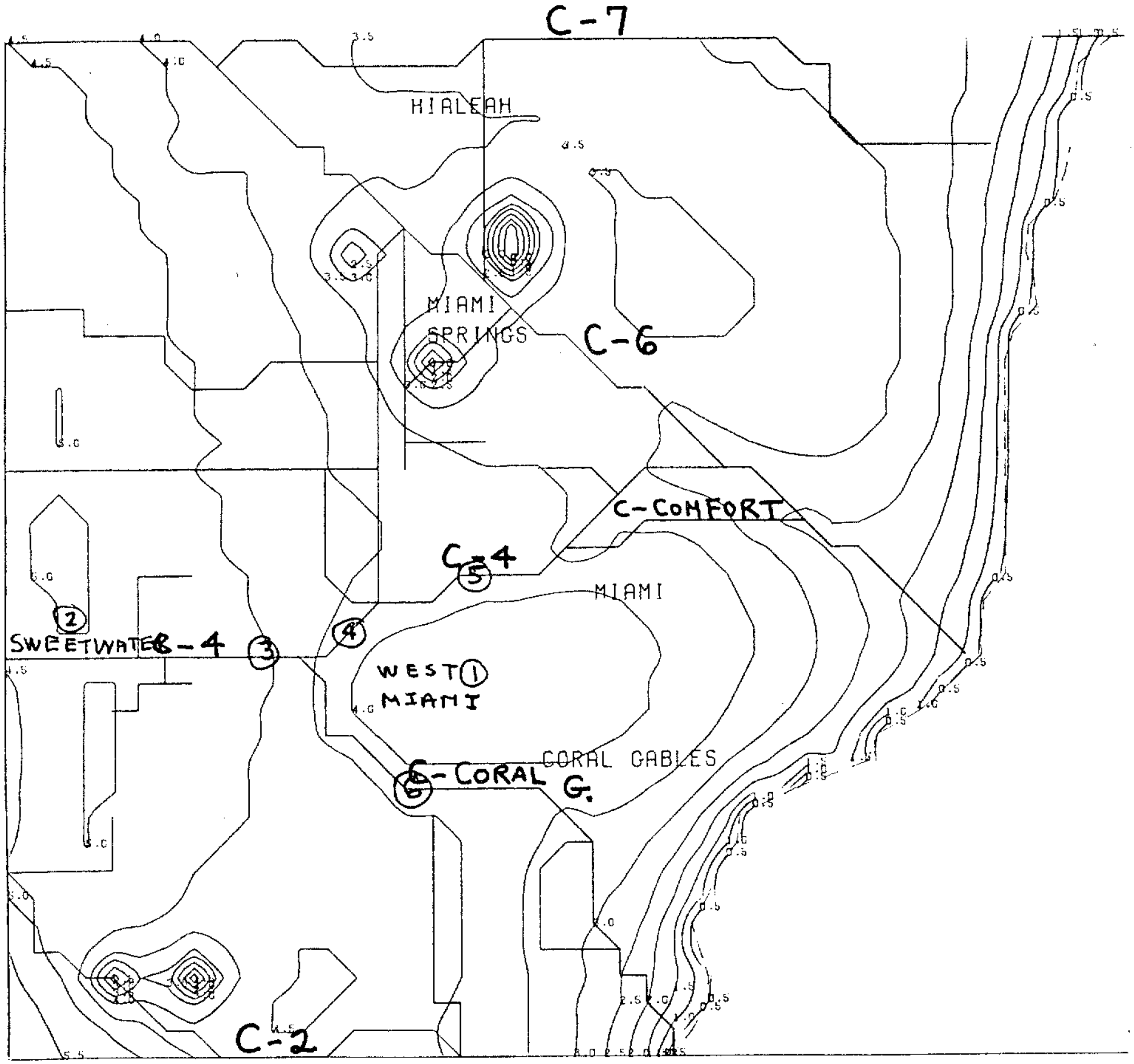
GROUNDWATER TABLE FOR END OF AUGUST 18 1981 - existing structures

Figure 3A-2



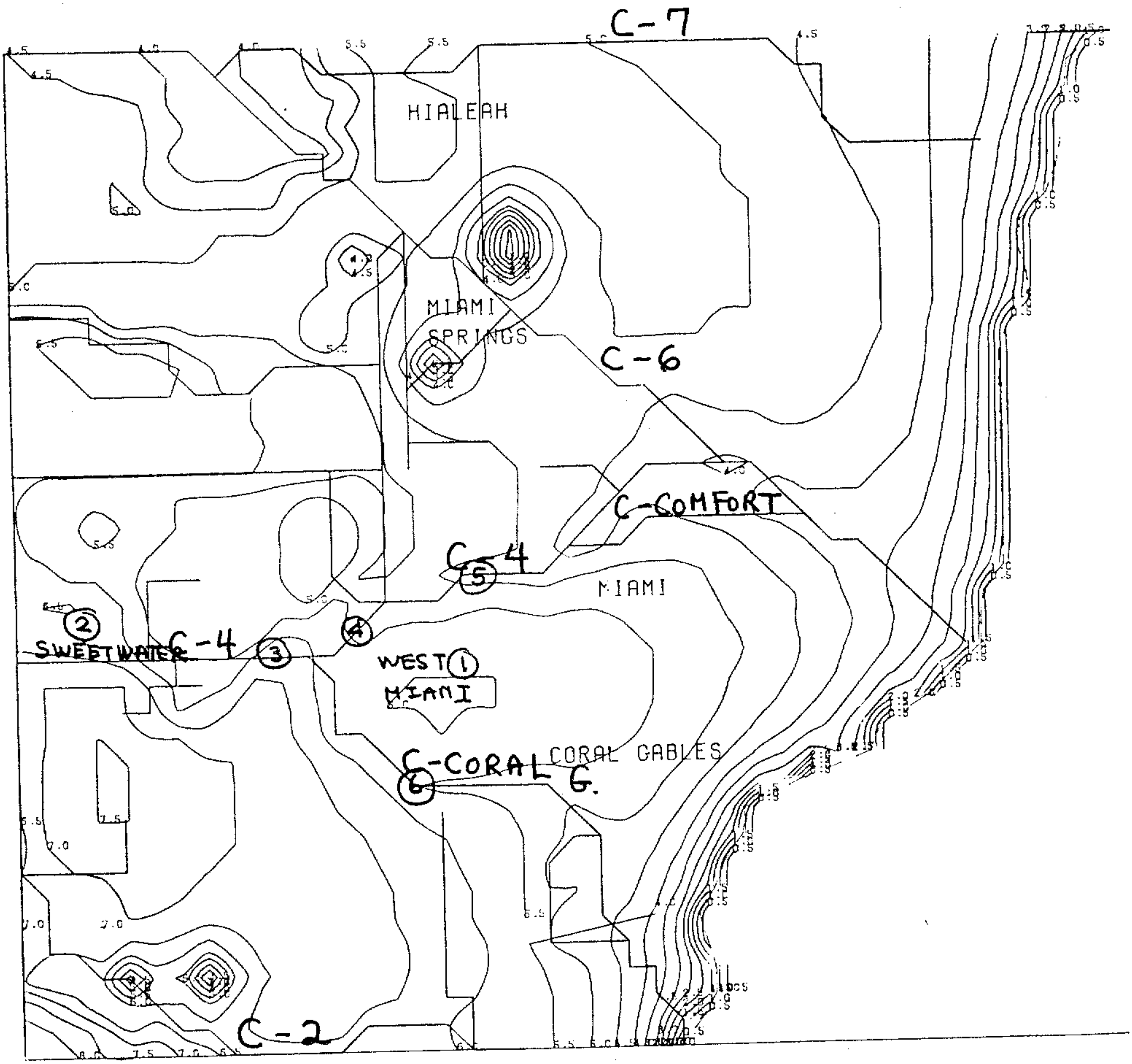
GROUNDWATER TABLE FOR END OF AUGUST 22 1981 - existing structures

Figure 3A-3



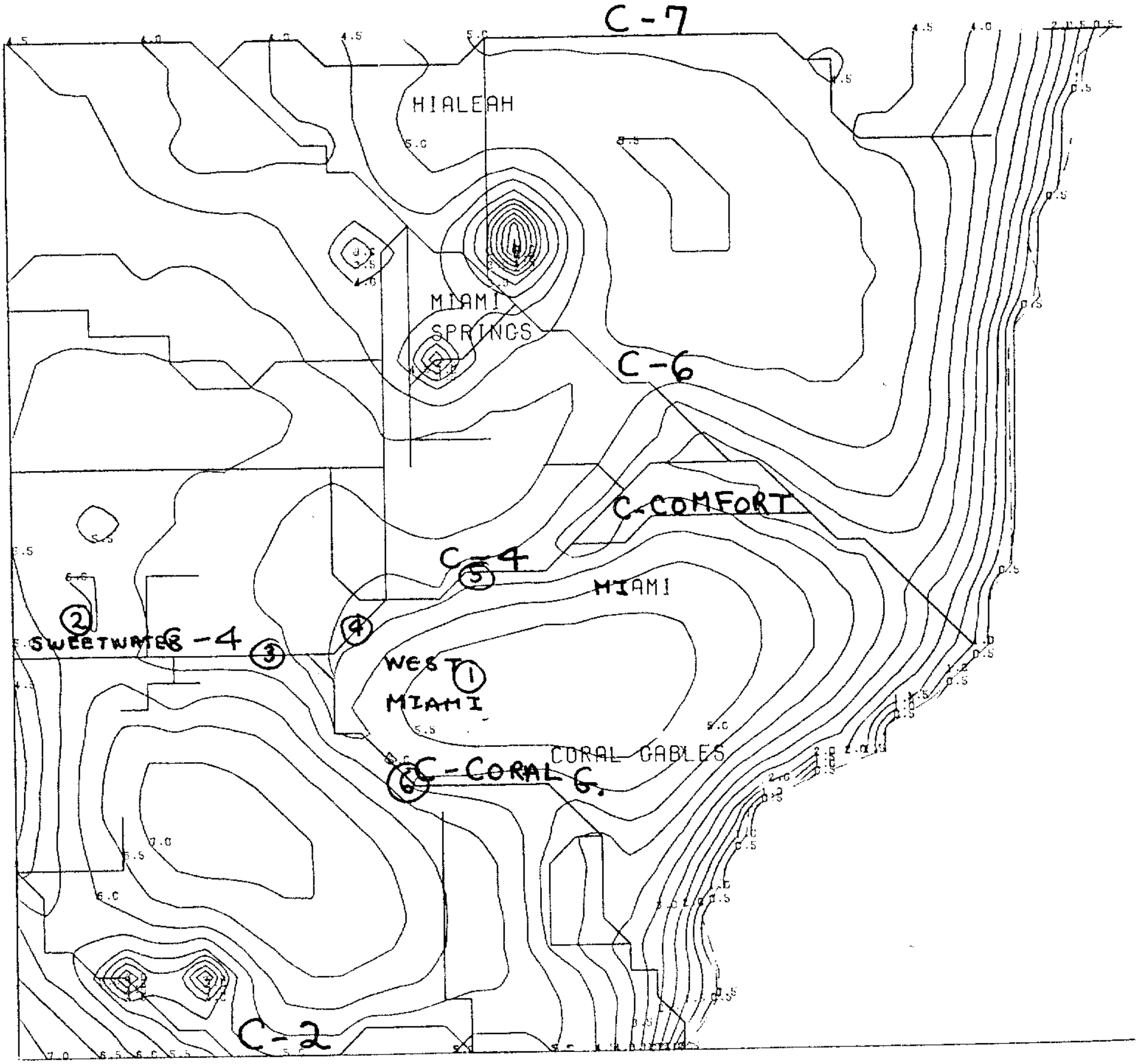
GROUNDWATER TABLE FOR END OF AUGUST 17 1981 - secondary structure at C-4 and C-Coral Gables (Alternative 1)

Figure 3B-1



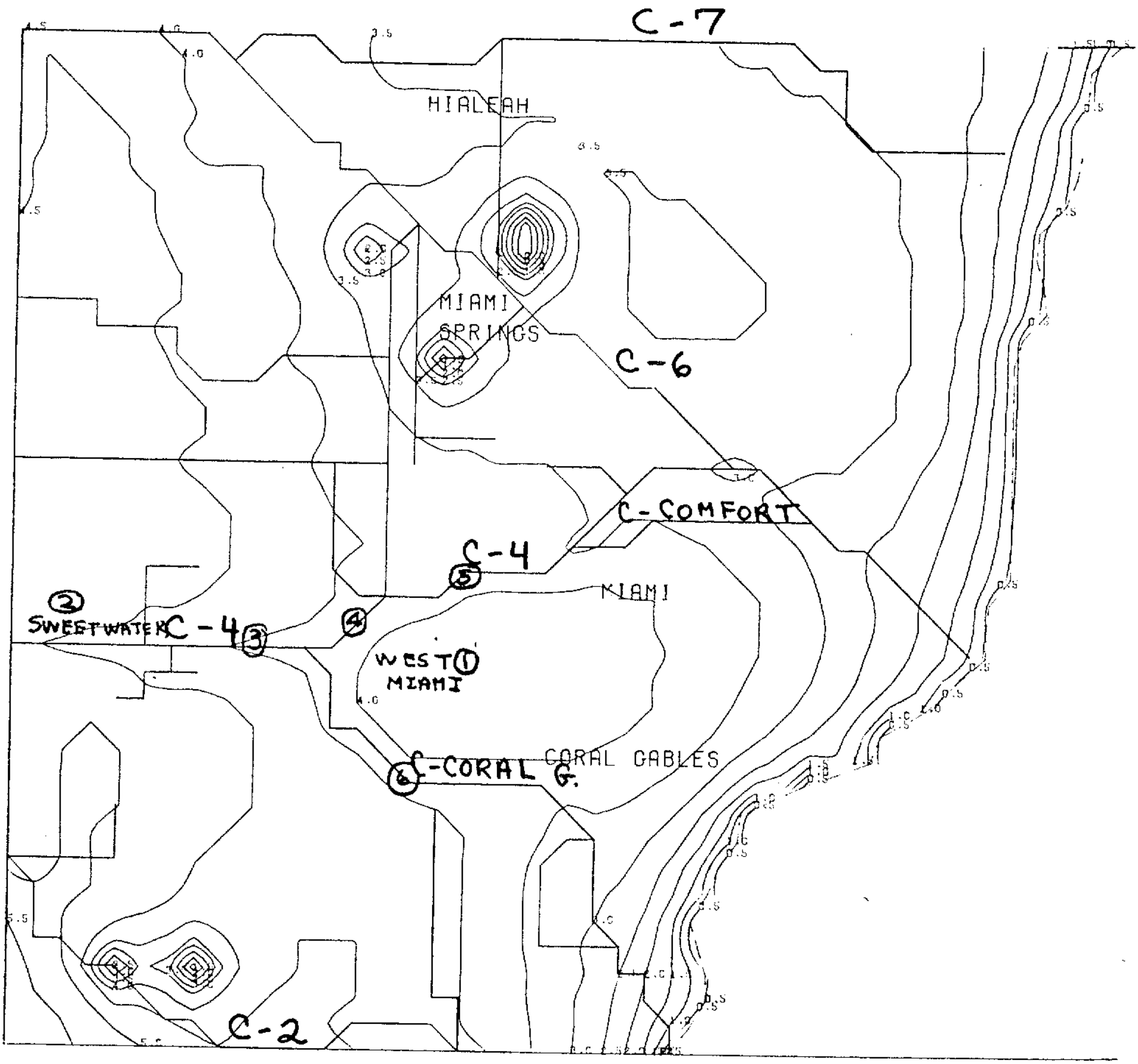
GROUNDWATER TABLE FOR END OF AUGUST 18 1981 - secondary structure at C-4 and C-Coral Gables (Alternative 1)

Figure 3B-2



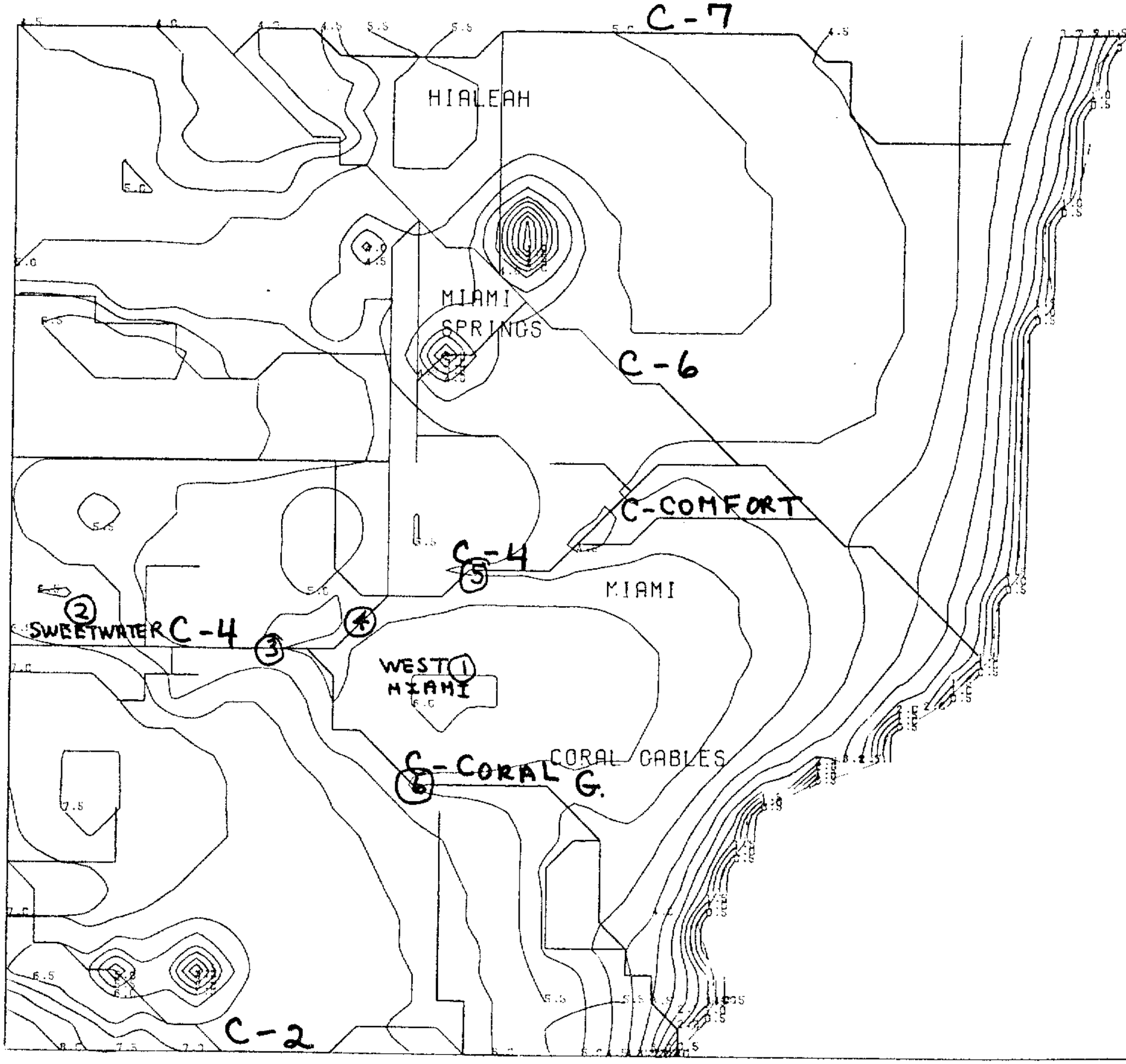
GROUNDWATER TABLE FOR END OF AUGUST 22 1981 - secondary structure at C-4 and C-Coral Gables (Alternative 1)

Figure 3B-3



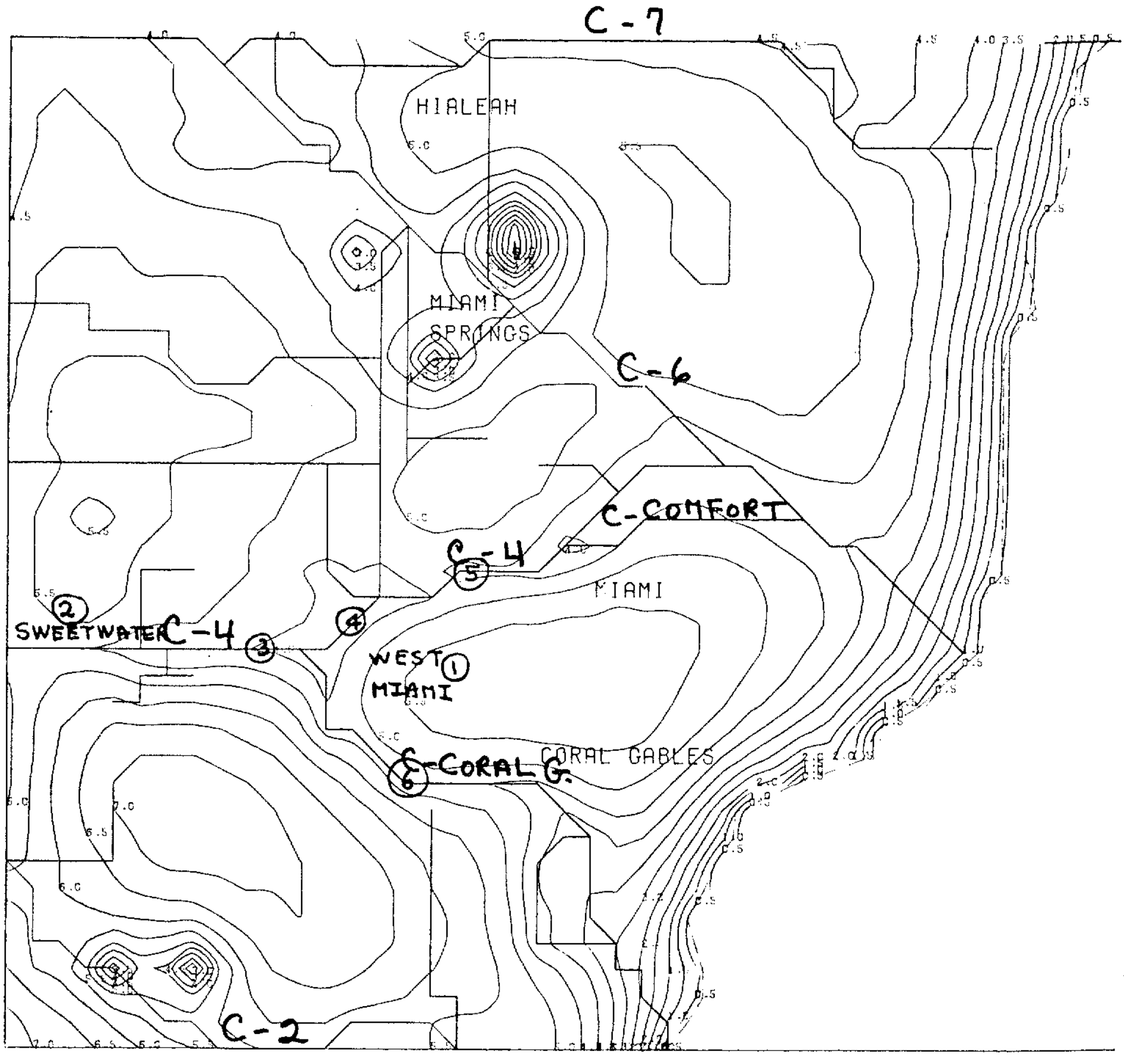
GROUNDWATER TABLE FOR END OF AUGUST 17 1981 - secondary structure at C-4 and C-Snapper Creek (Alternative 2)

Figure 3C-1



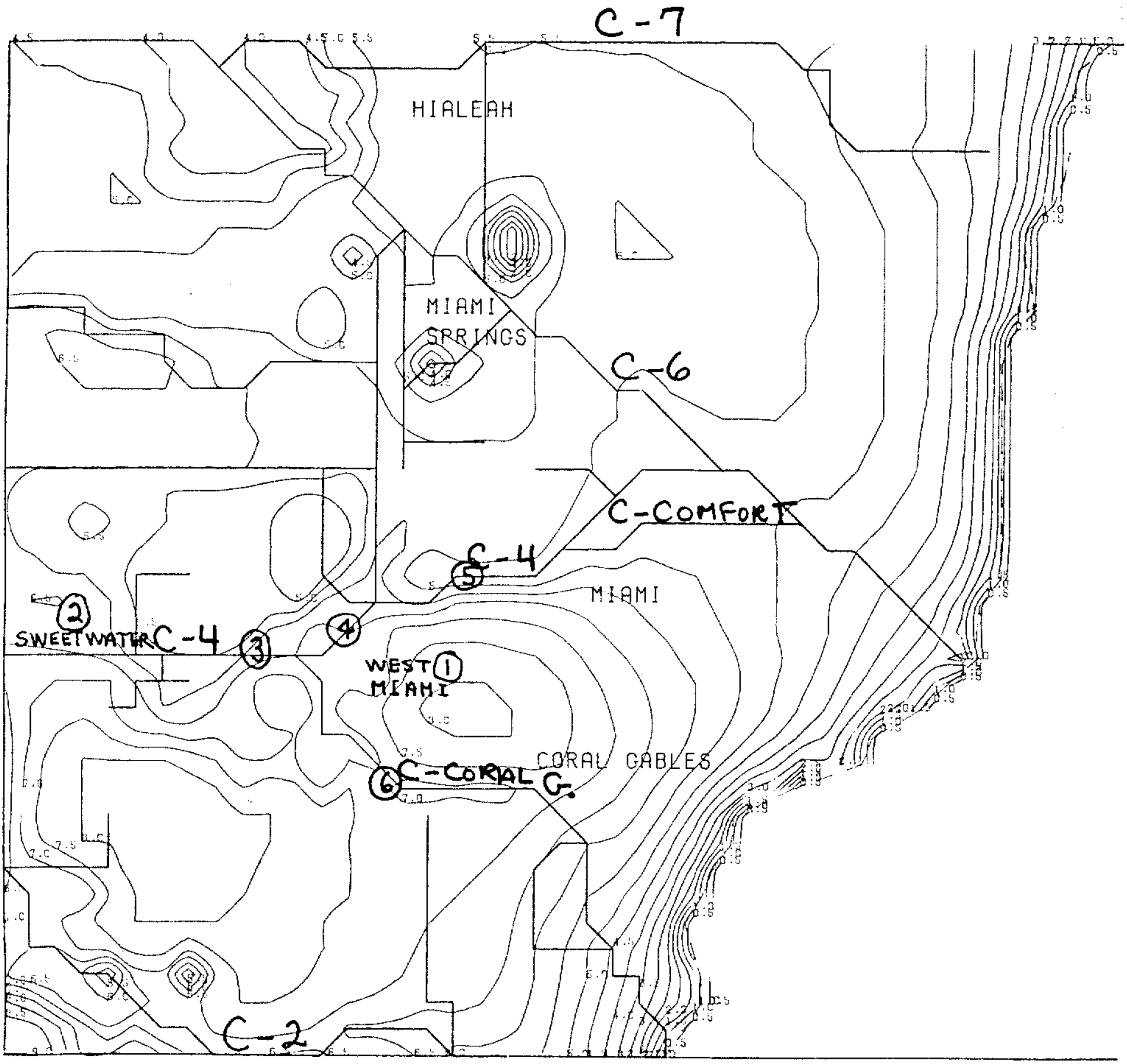
GROUNDWATER TABLE FOR END OF AUGUST 18 1981 - secondary structure at C-4 and C-Snapper Creek (Alternative 2)

Figure 3C-2



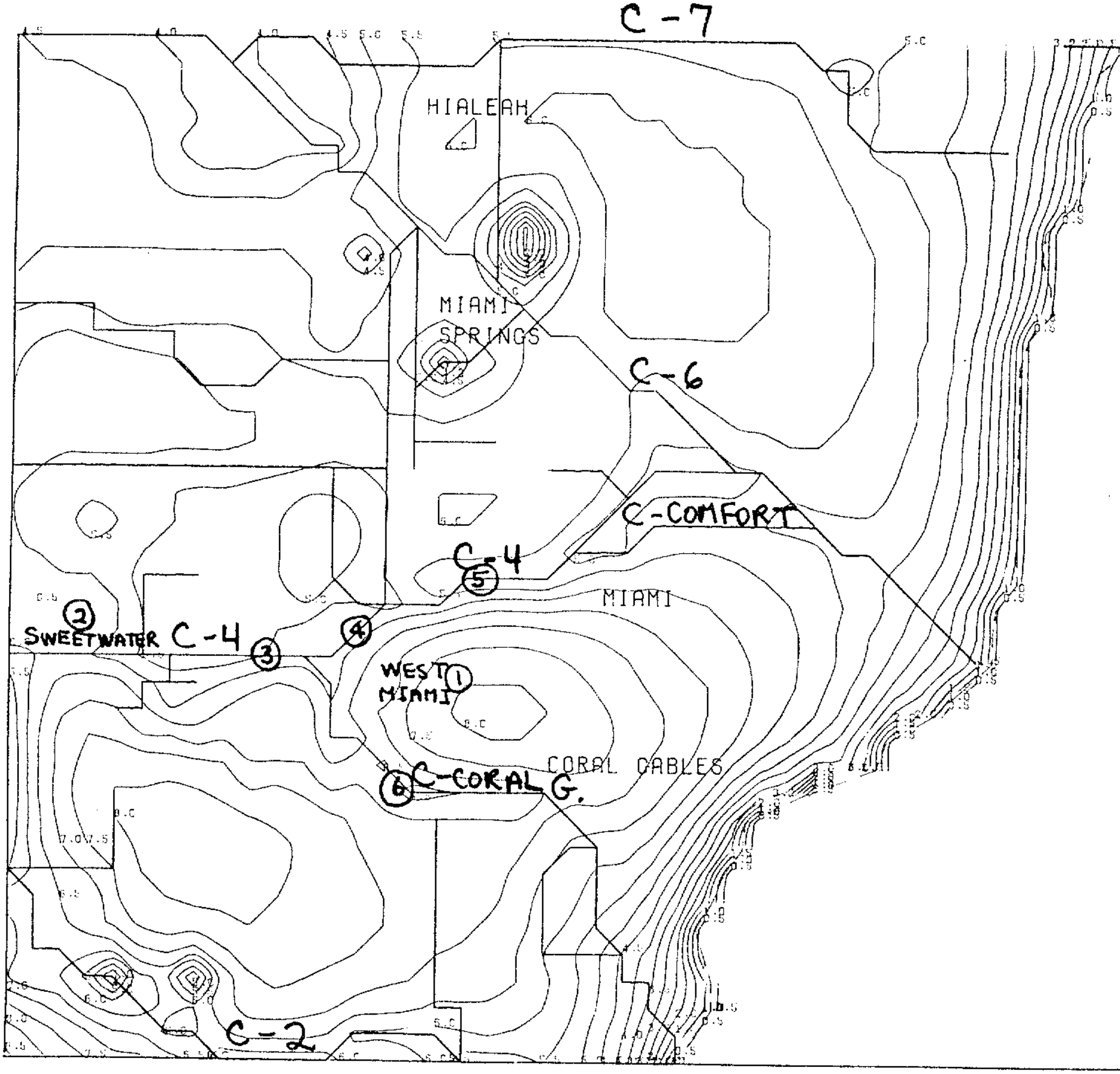
GROUNDWATER TABLE FOR END OF AUGUST 22 1981 - secondary structure at C-4 and C-Snapper Creek (Alternative 2)

Figure 3C-3



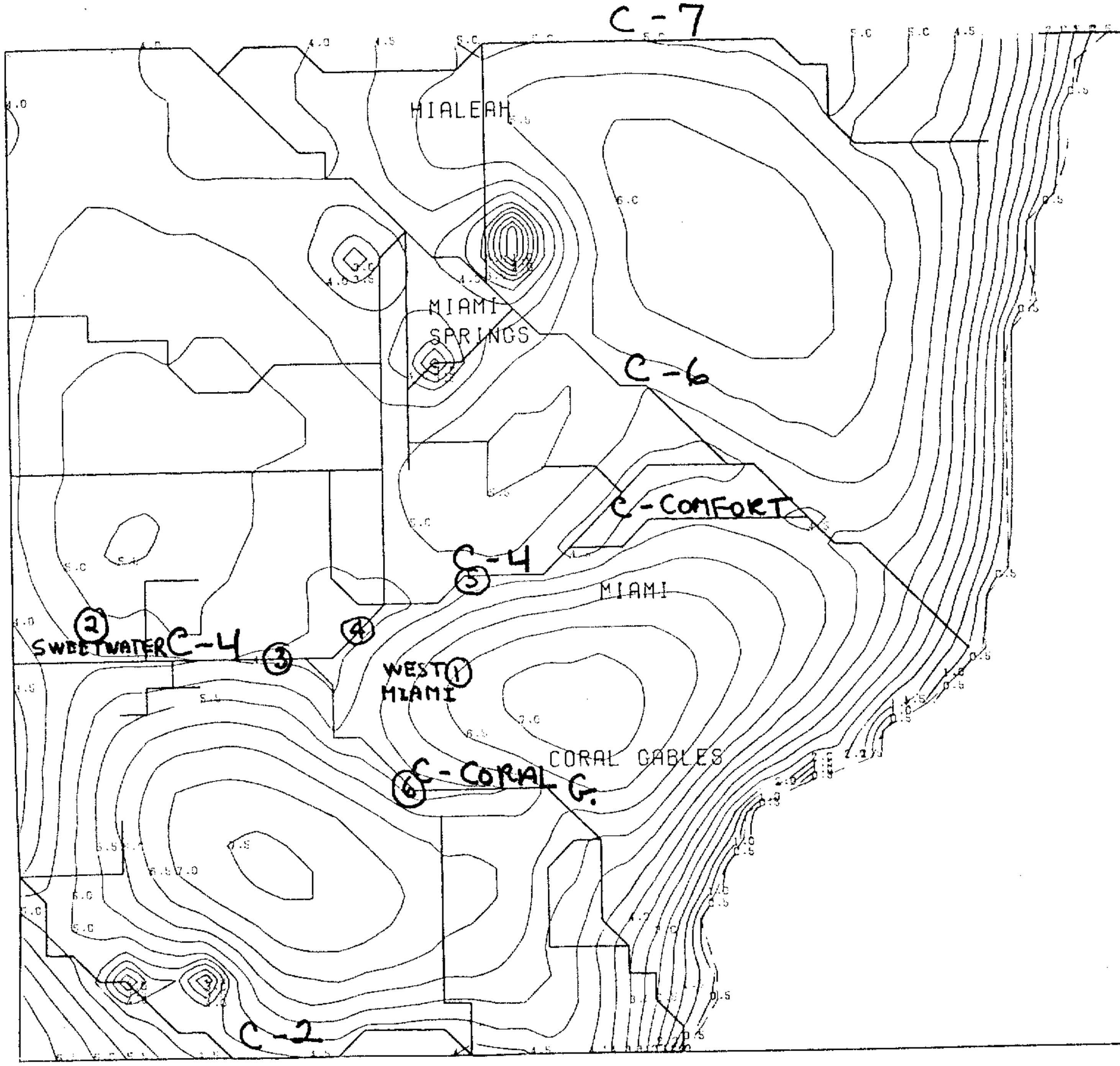
GROUNDWATER TABLE FOR END OF APRIL 24 1982 - existing structures (present system)

Figure 4A- 1



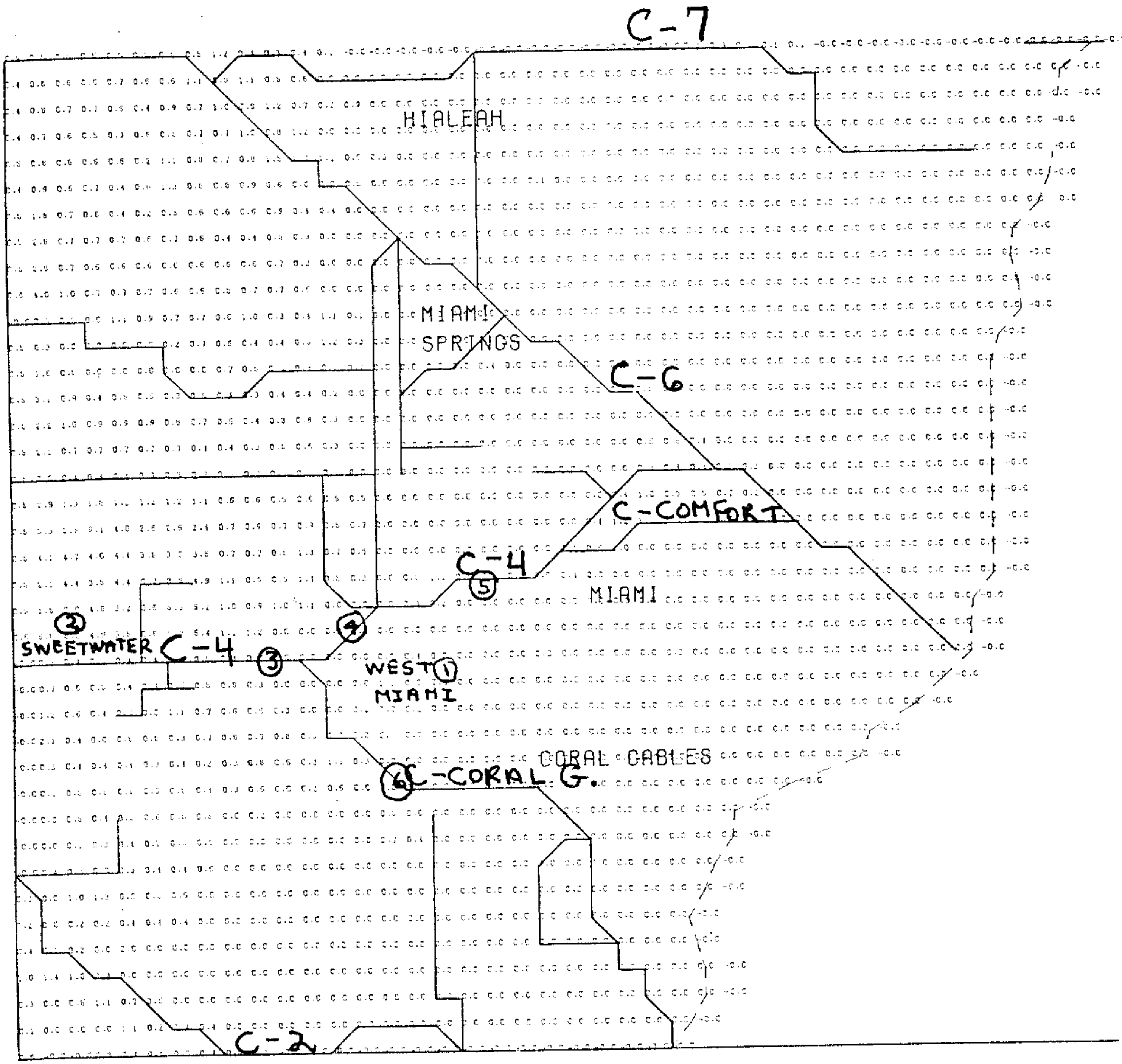
GROUNDWATER TABLE FOR END OF APRIL 25 1982 - existing structures (present system)

Figure 4A-2



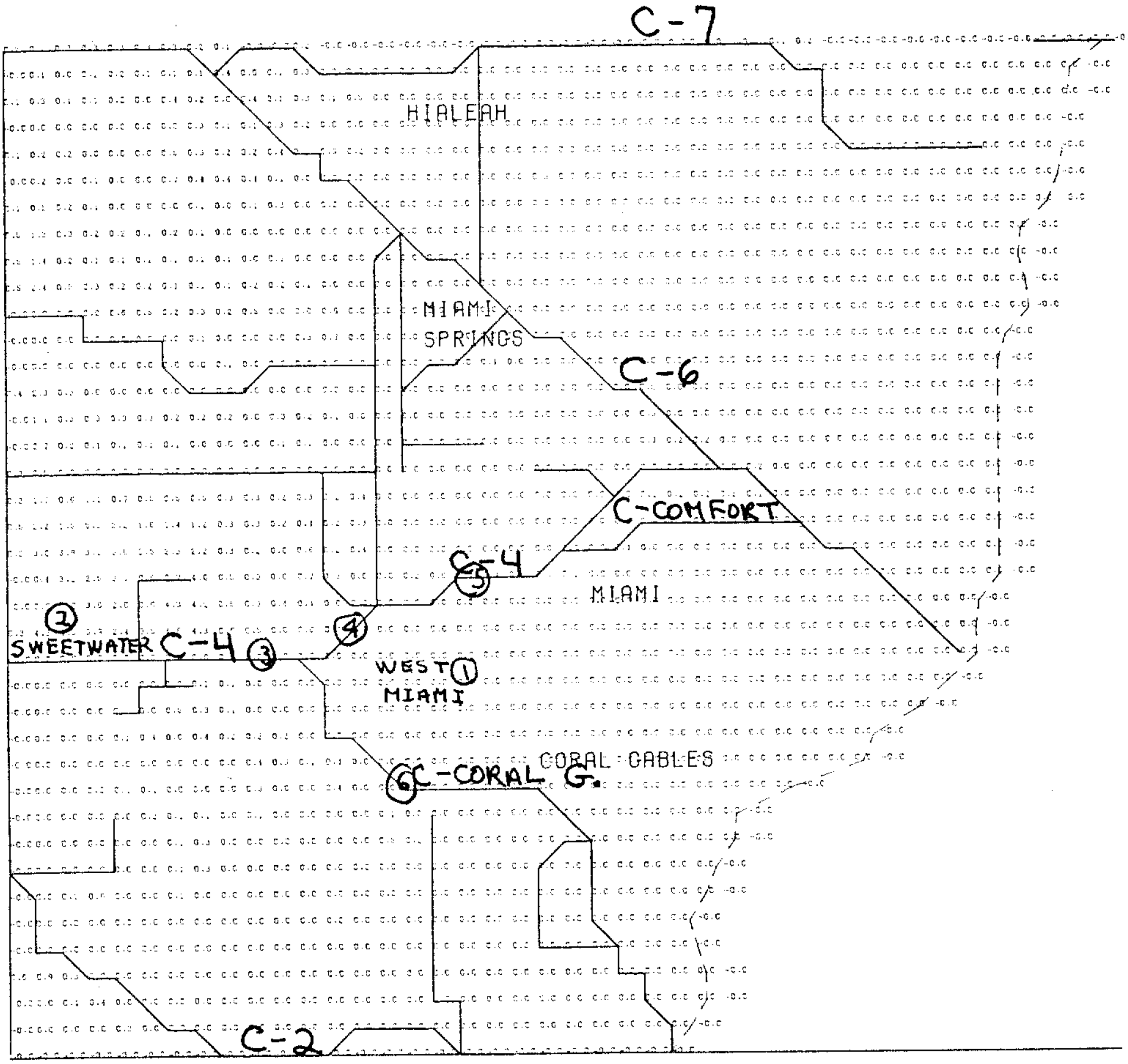
GROUNDWATER TABLE FOR END OF APRIL 30 1982 - existing structures (present system)

Figure 4A-3



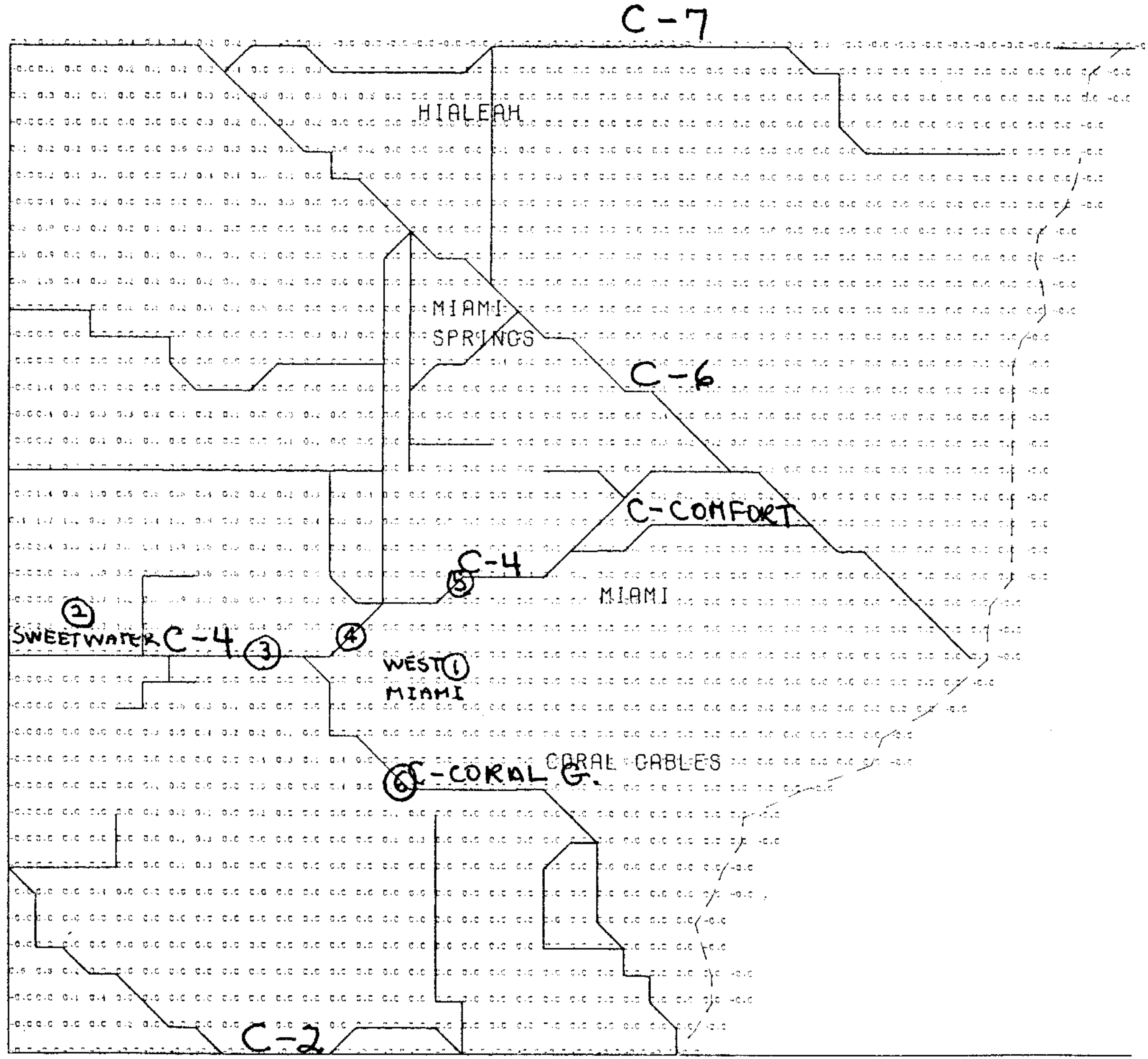
PONDING DEPTH.IN FEET*10 FOR END OF APRIL 24 1982 - existing structures (present system)

Figure 4A- 4



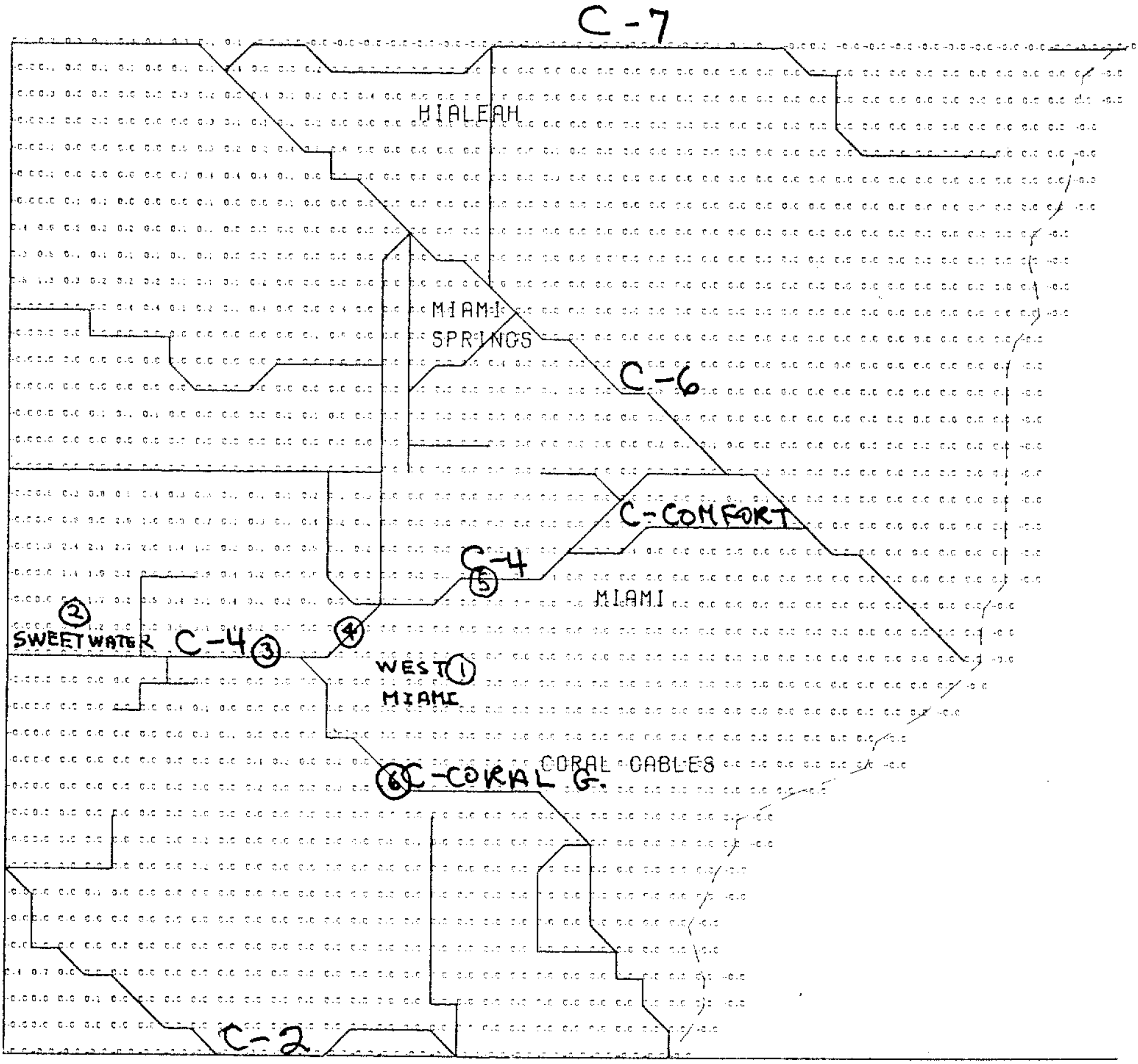
PONDING DEPTH.IN FEET*10 FOR END OF APRIL 25 1982 - existing structures (present system)

Figure 4A-5



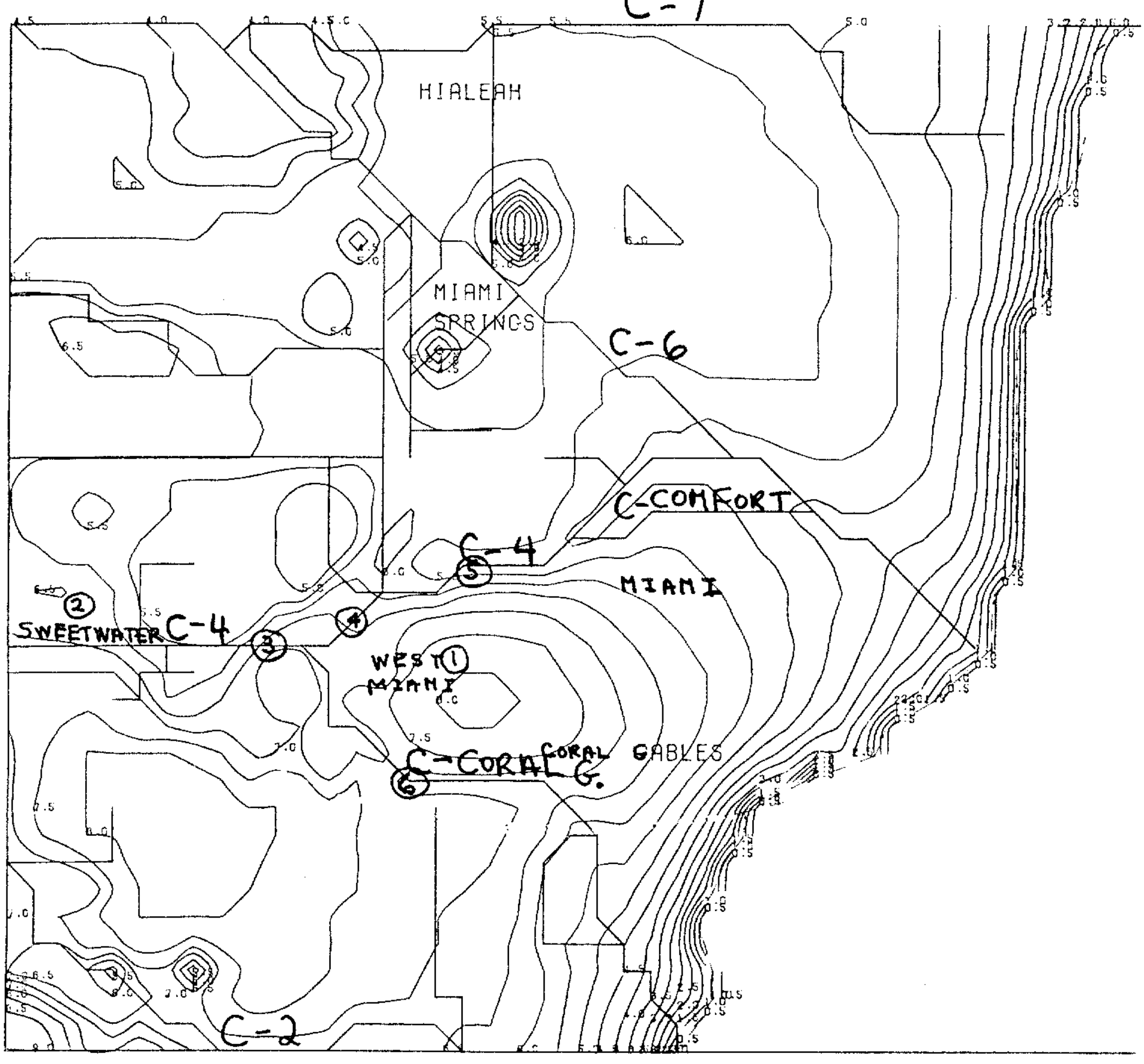
PONDING DEPTH.IN FEET*10 FOR END OF APRIL 26 1982 - existing structures (present system)

Figure 4A-6



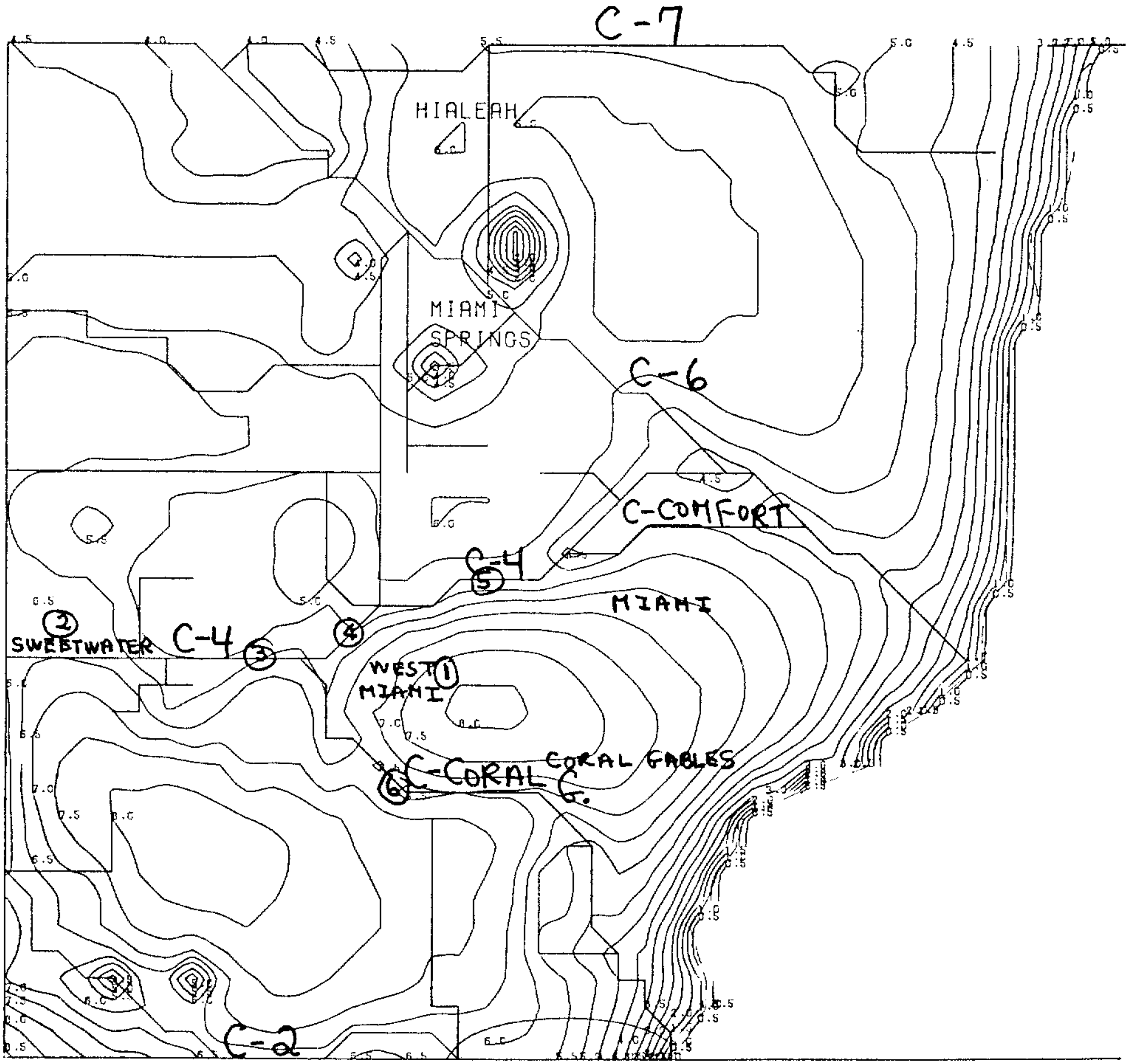
PONDING DEPTH.IN FEET*10 FOR END OF APRIL 27 1982 - existing structures (present system)

Figure 4A-7



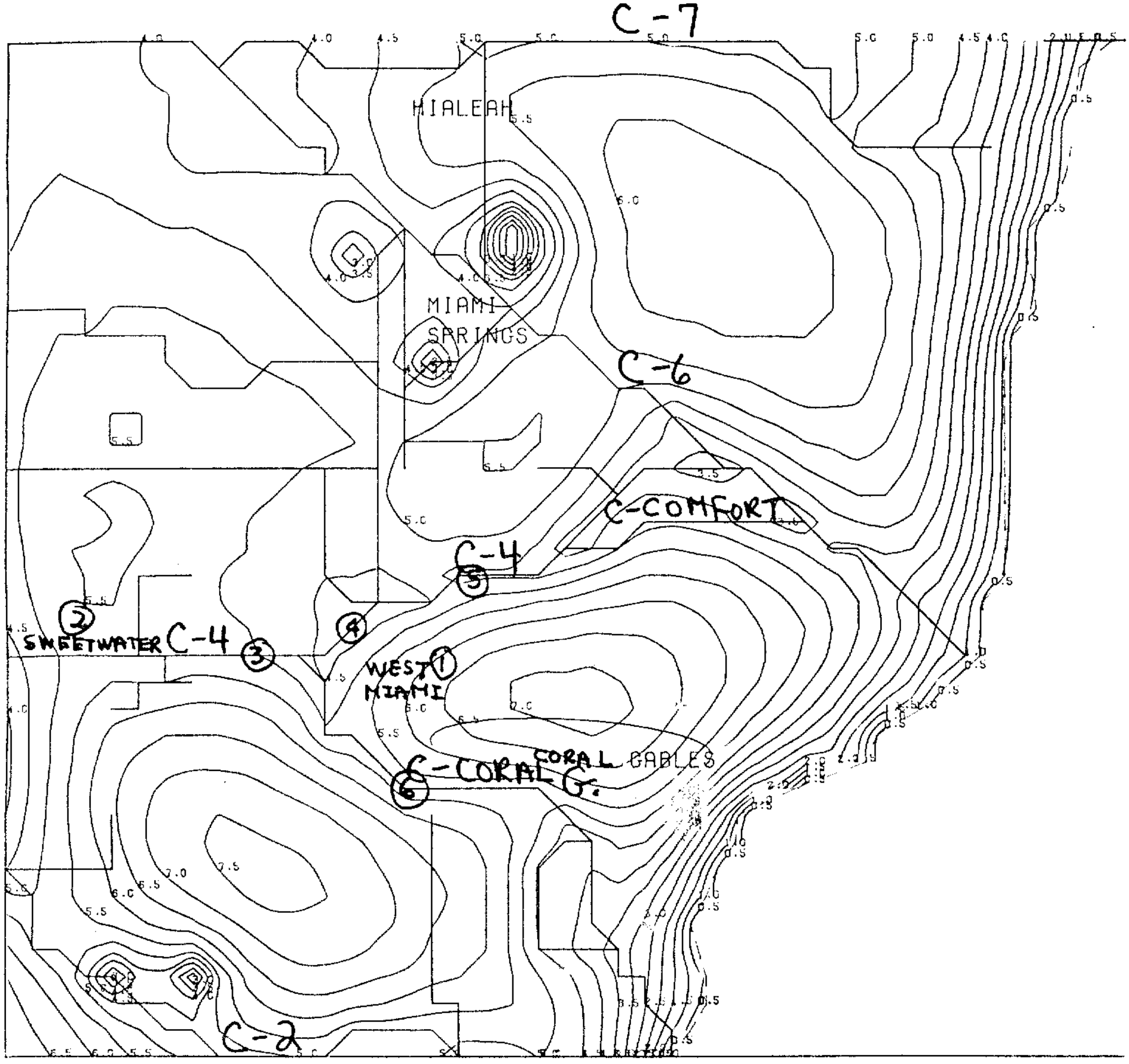
GROUNDWATER TABLE FOR END OF APRIL 24 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-1



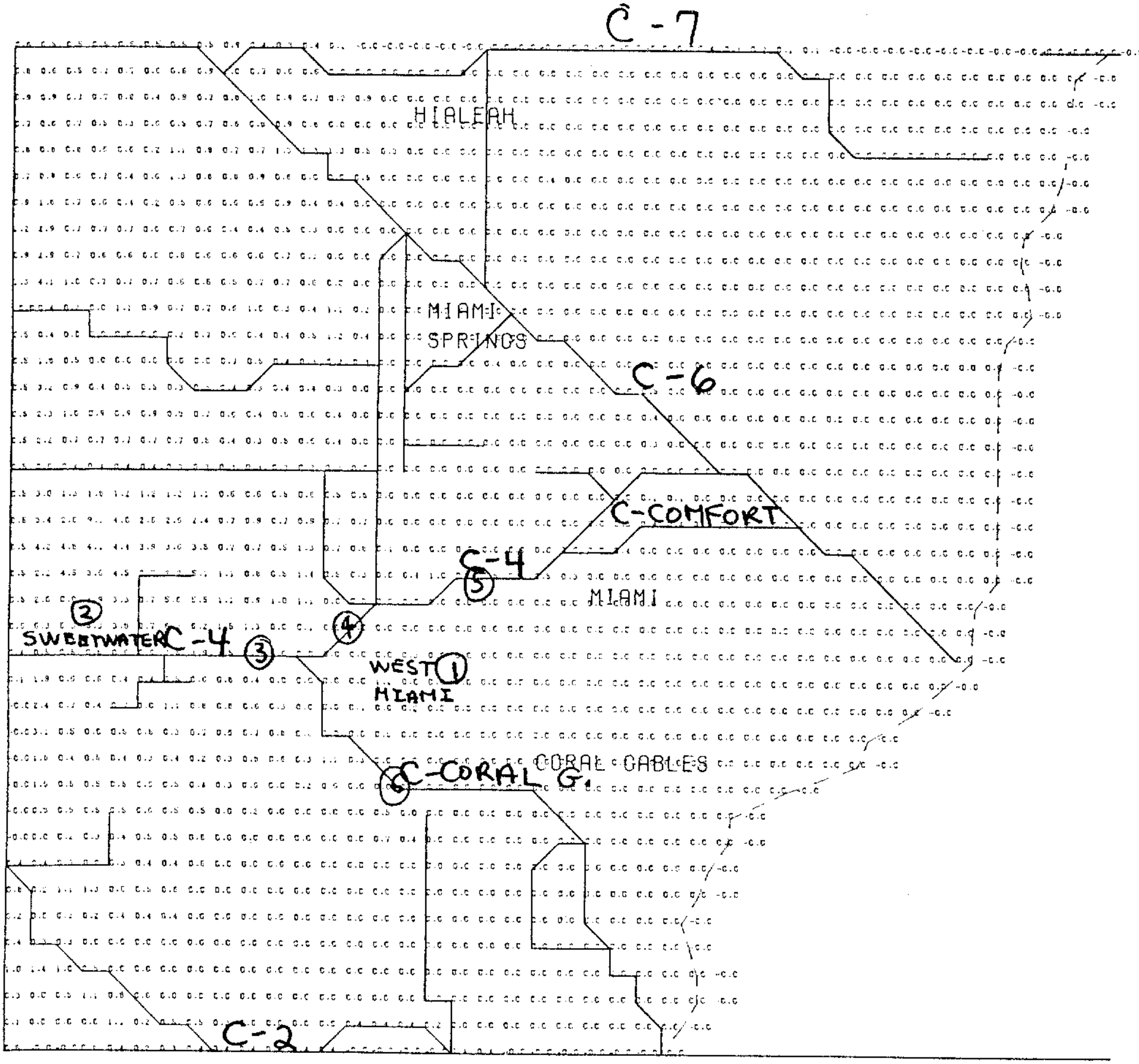
GROUNDWATER TABLE FOR END OF APRIL 25 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-2



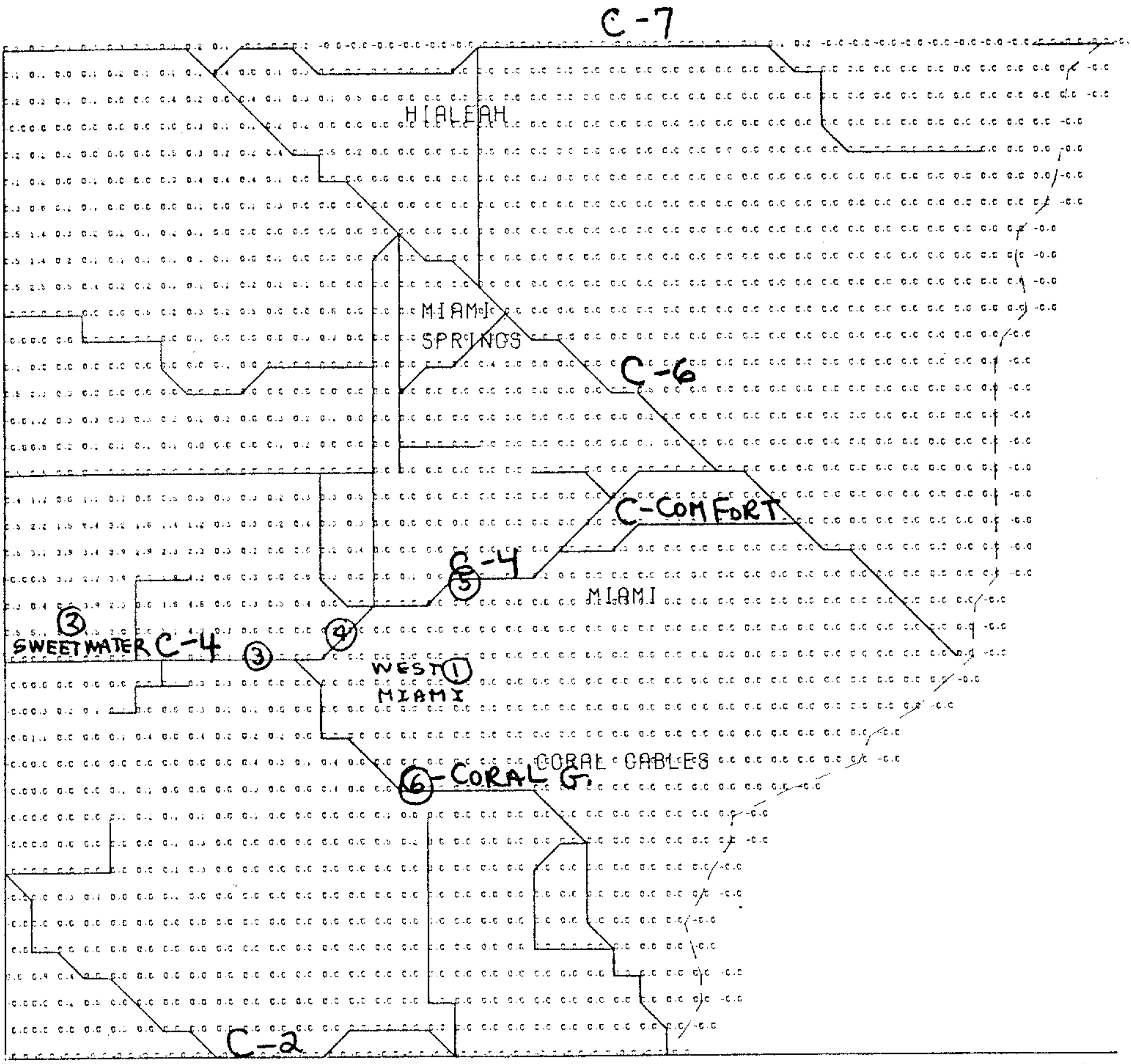
GROUNDWATER TABLE FOR END OF APRIL 30 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-3



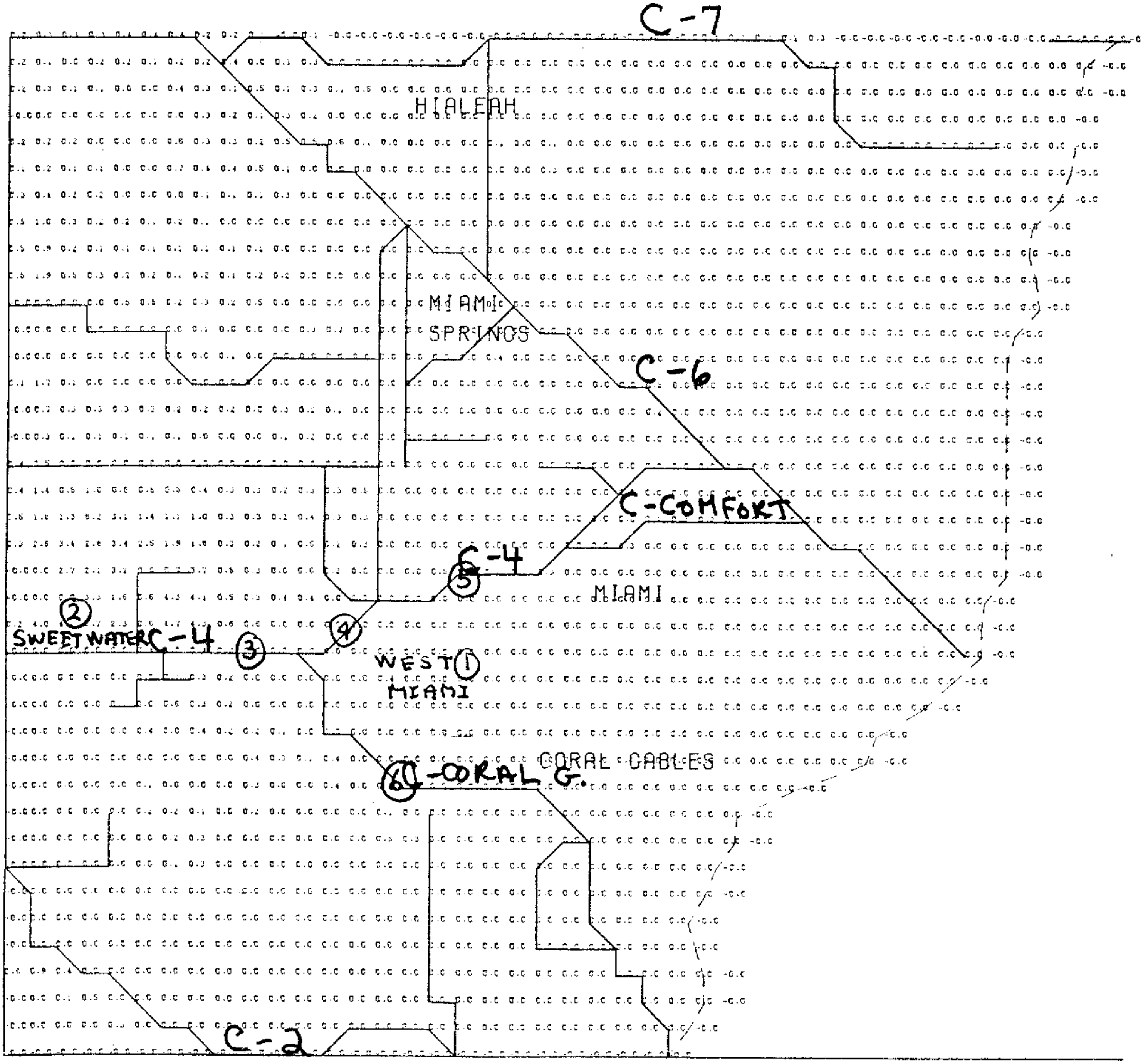
PONDING DEPTH, IN FEET*10 FOR END OF APRIL 24 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-4



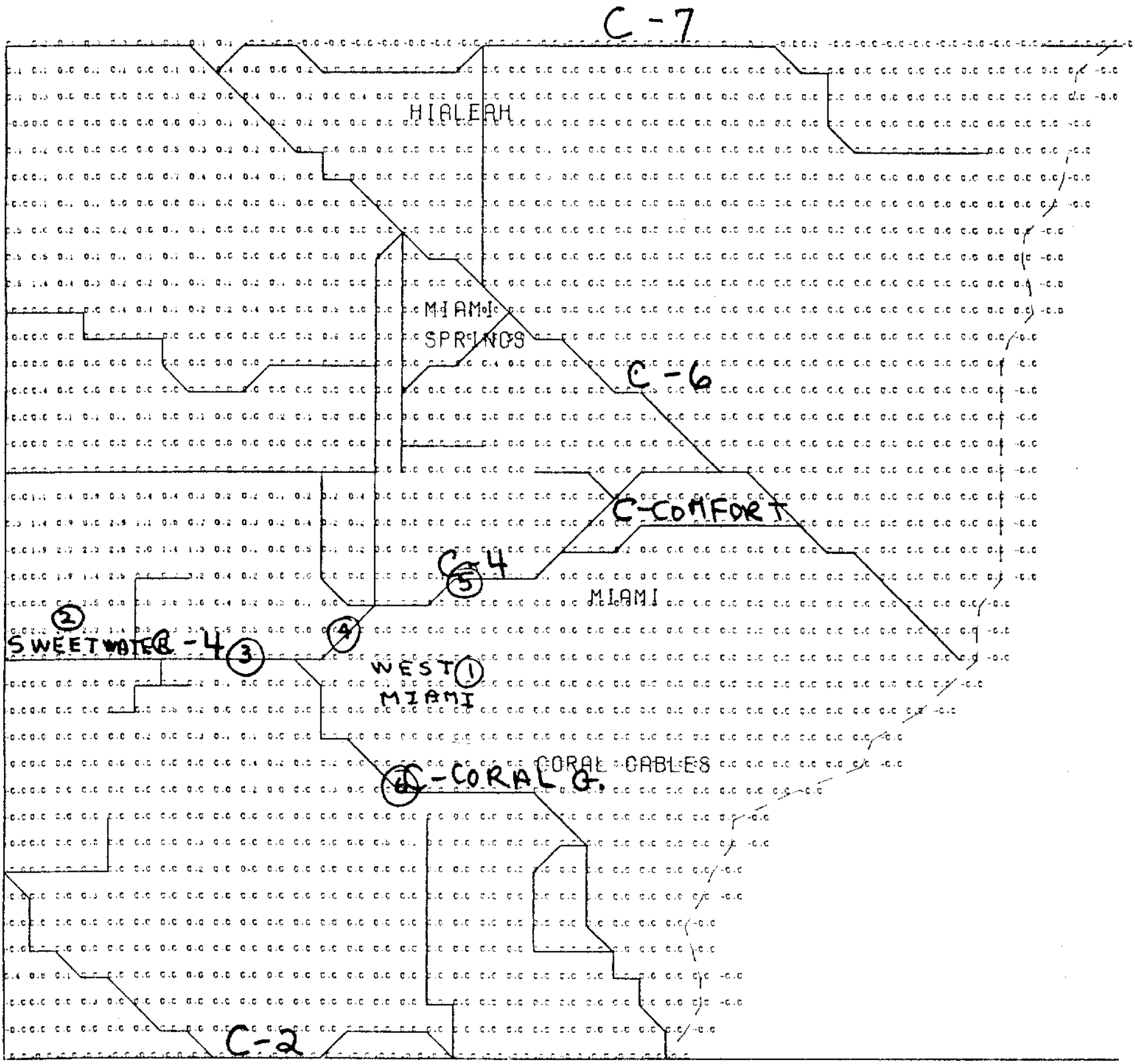
PONDING DEPTH IN FEET*10 FOR END OF APRIL 25 1982 - secondary structure at C-4 & C-Coral Gables
(Alternative 1)

Figure 4B-5



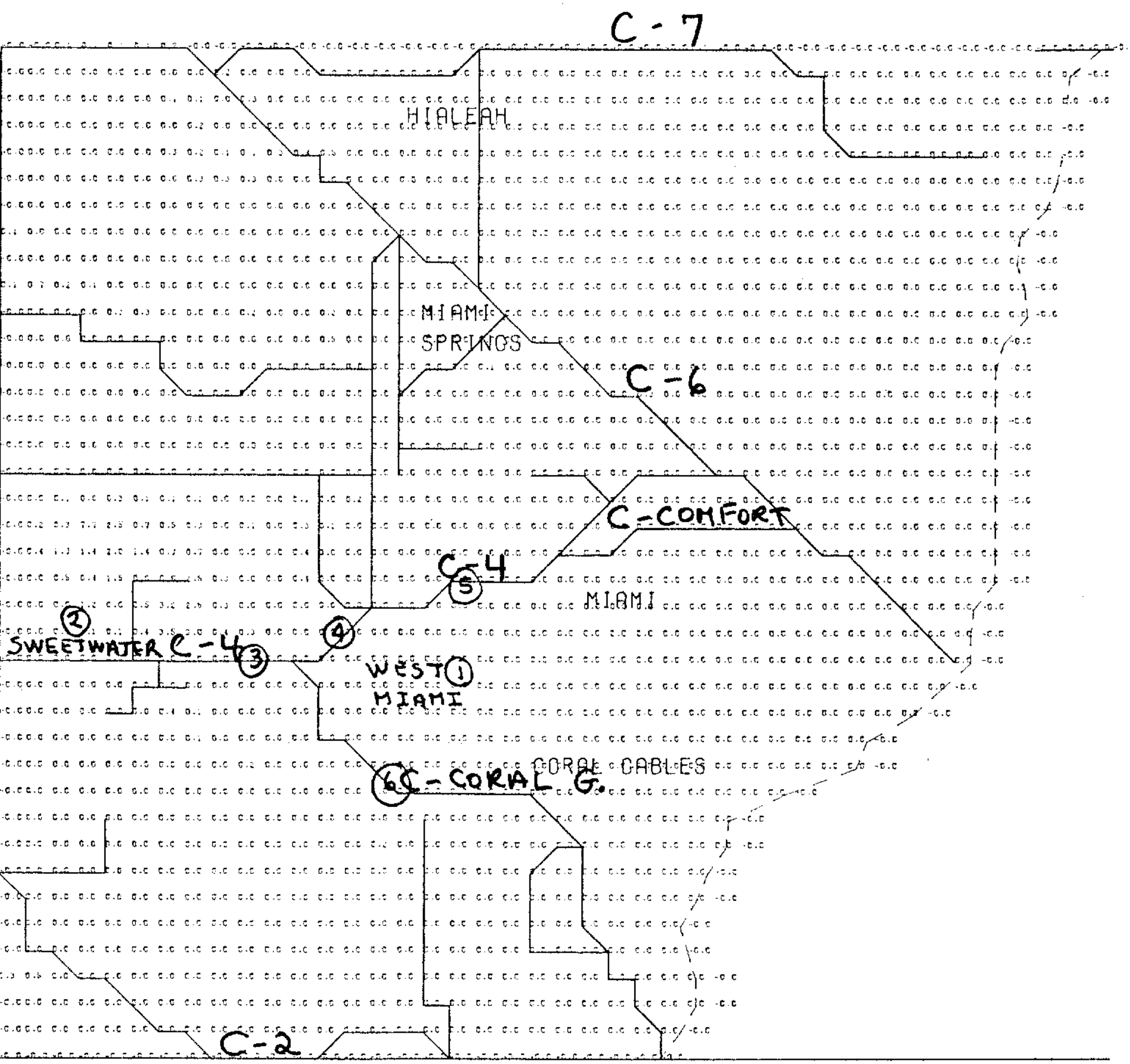
PONDING DEPTH, IN FEET*10 FOR END OF APRIL 26 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-6



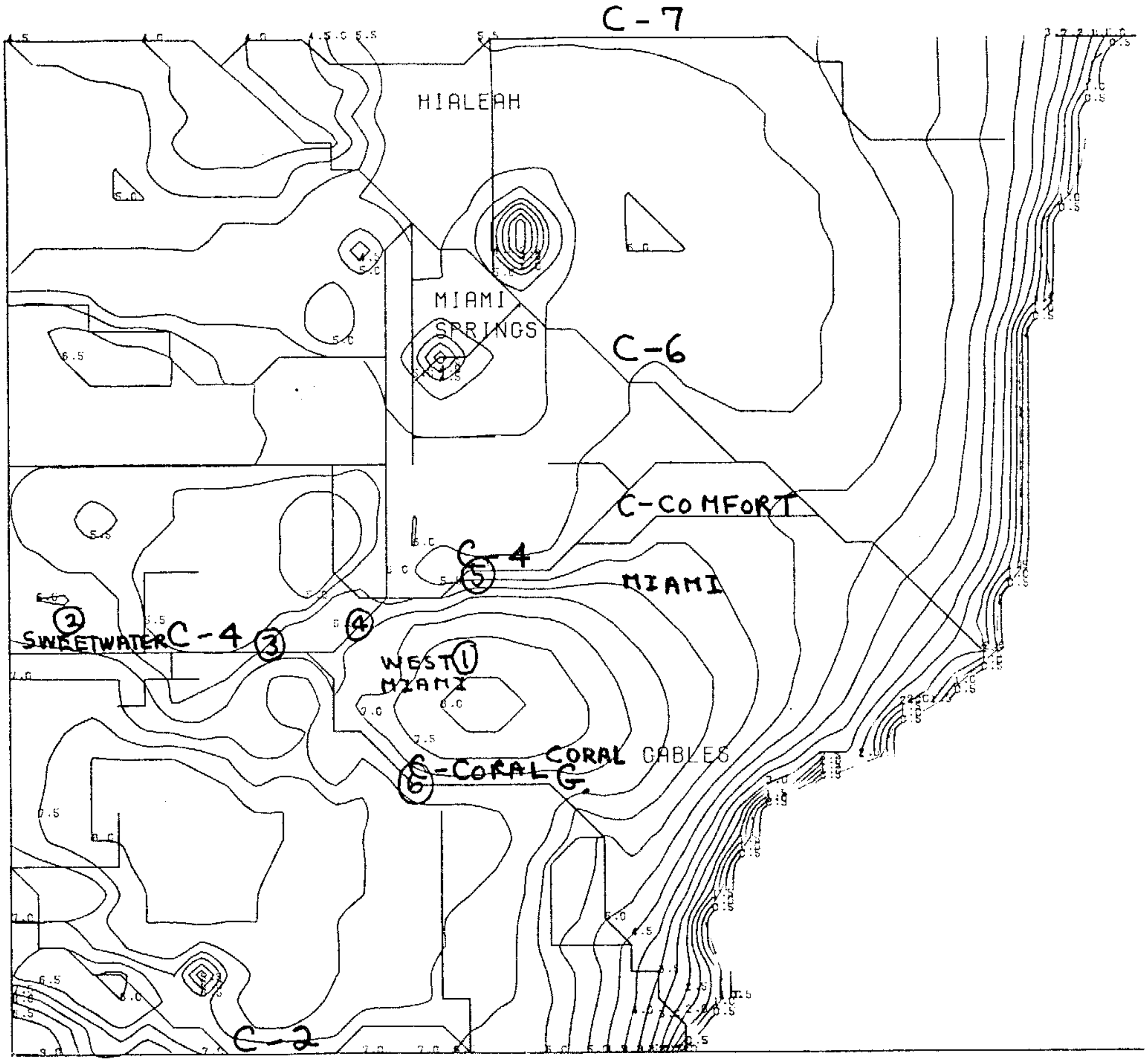
PONDING DEPTH.IN FEET*10 FOR END OF APRIL 27 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-7



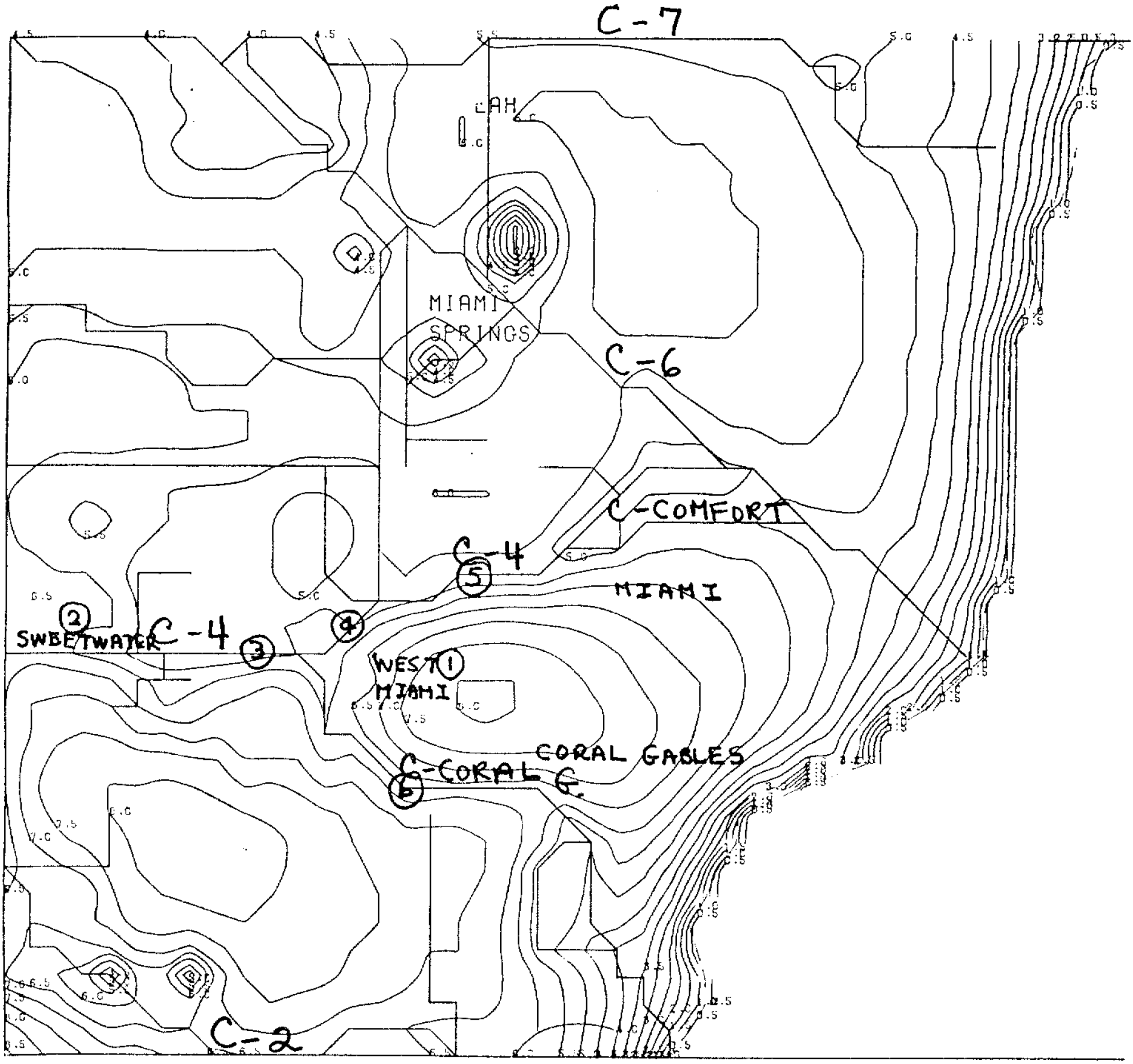
PONDING DEPTH,IN FEET*10 FOR END OF APRIL 28 1982 - secondary structure at C-4 & C-Coral Gables (Alternative 1)

Figure 4B-8



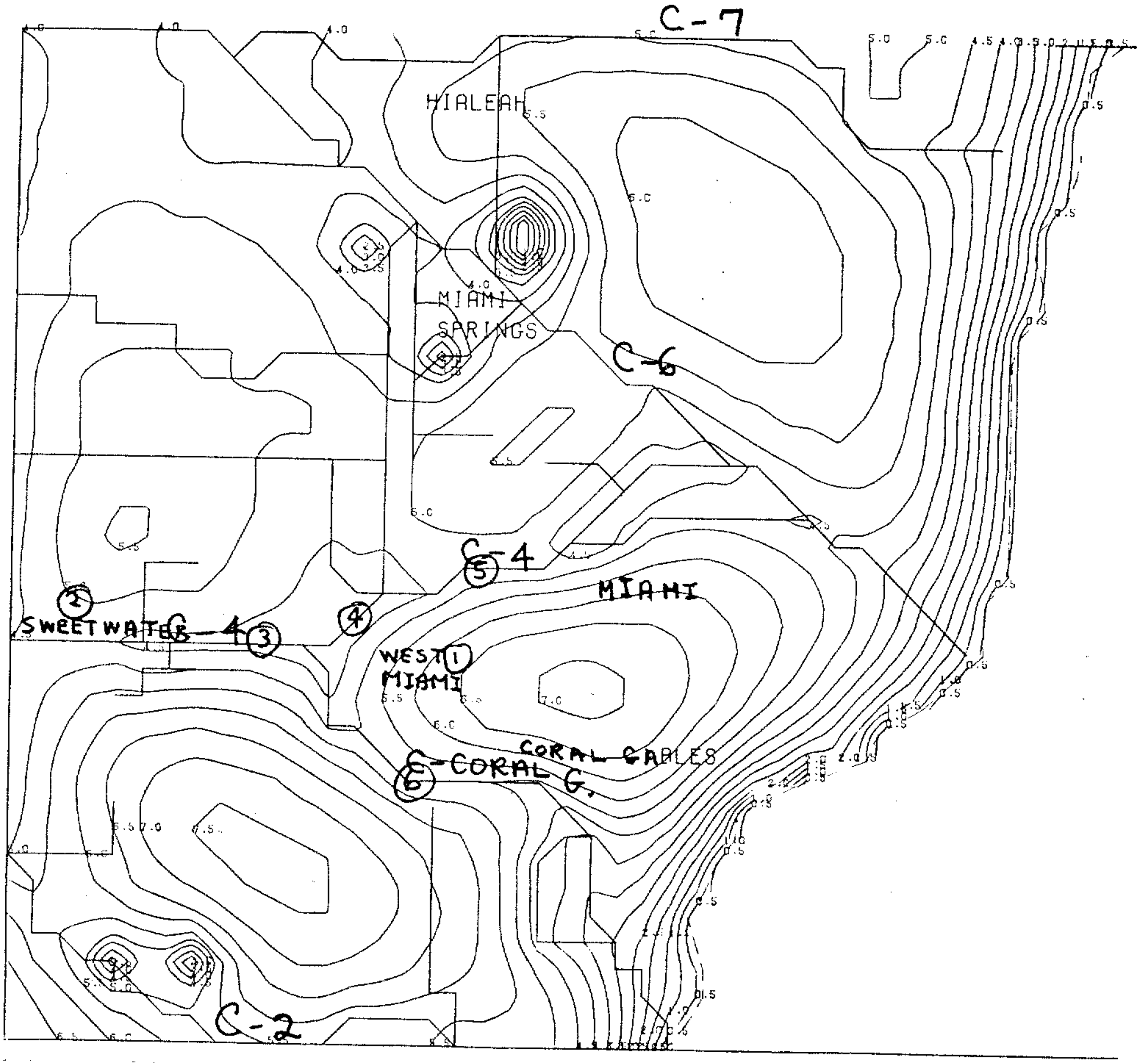
GROUNDWATER TABLE FOR END OF APRIL 24 1982 - secondary structure at C-4 & C-Snapper Creek
(Alternative 2)

Figure 4C-1



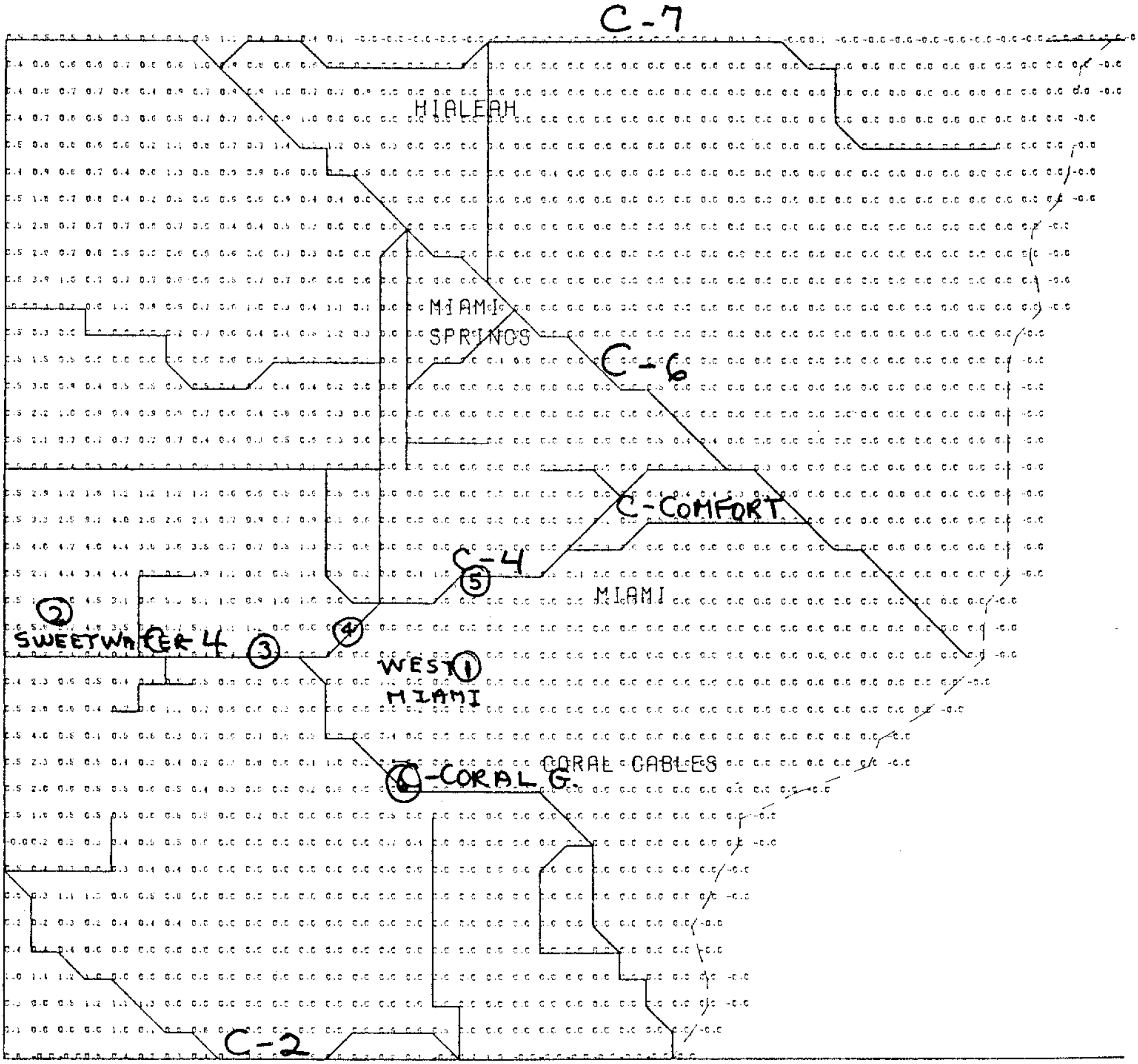
GROUNDWATER TABLE FOR END OF APRIL 25 1982 - secondary structure at C-4 & C-Snapper Creek (Alternative 2)

Figure 4C-2



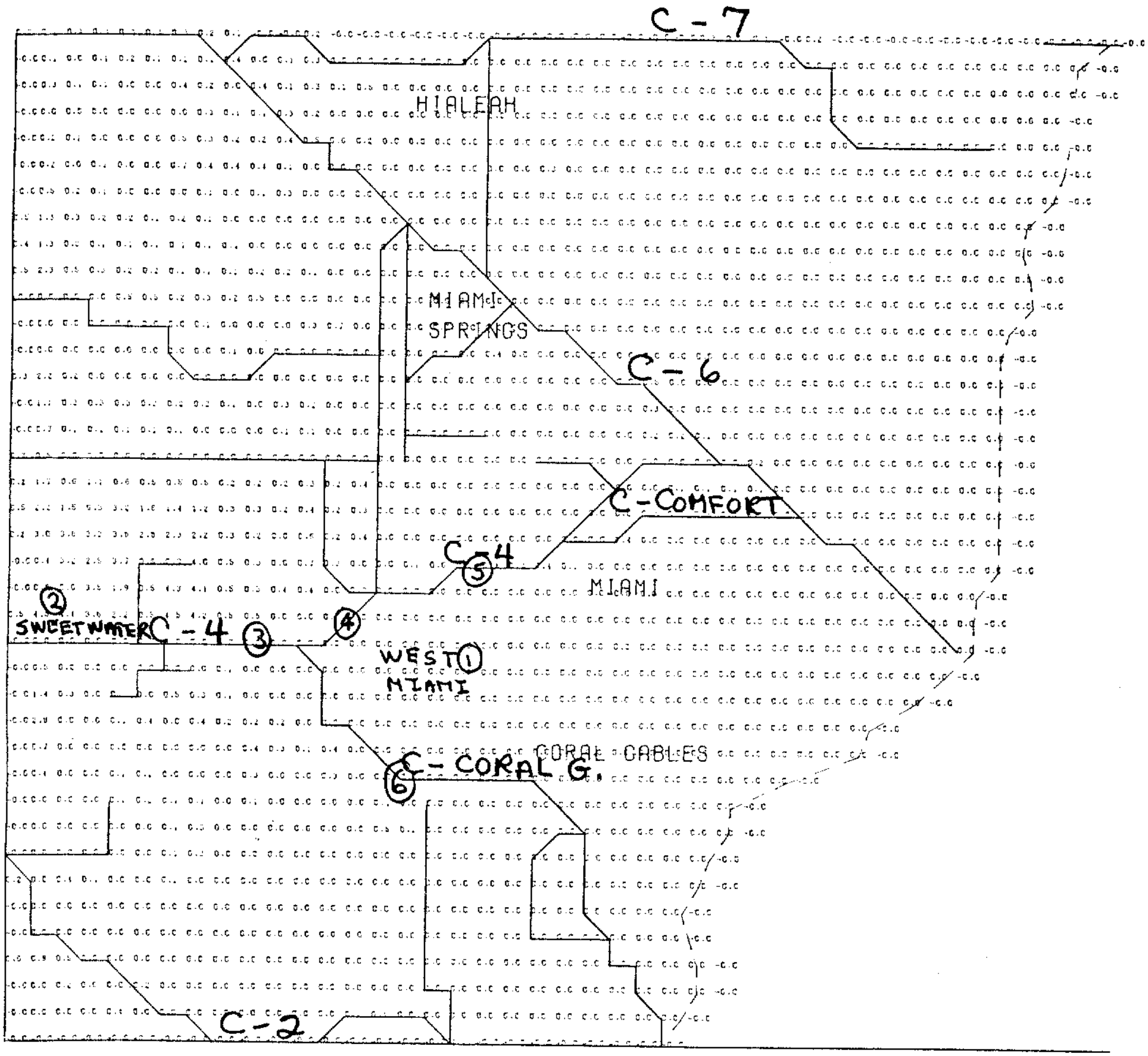
GROUNDWATER TABLE FOR END OF APRIL 30 1982 - secondary structure at C-4 & C-Snapper Creek (Alternative 2)

Figure 4C-3



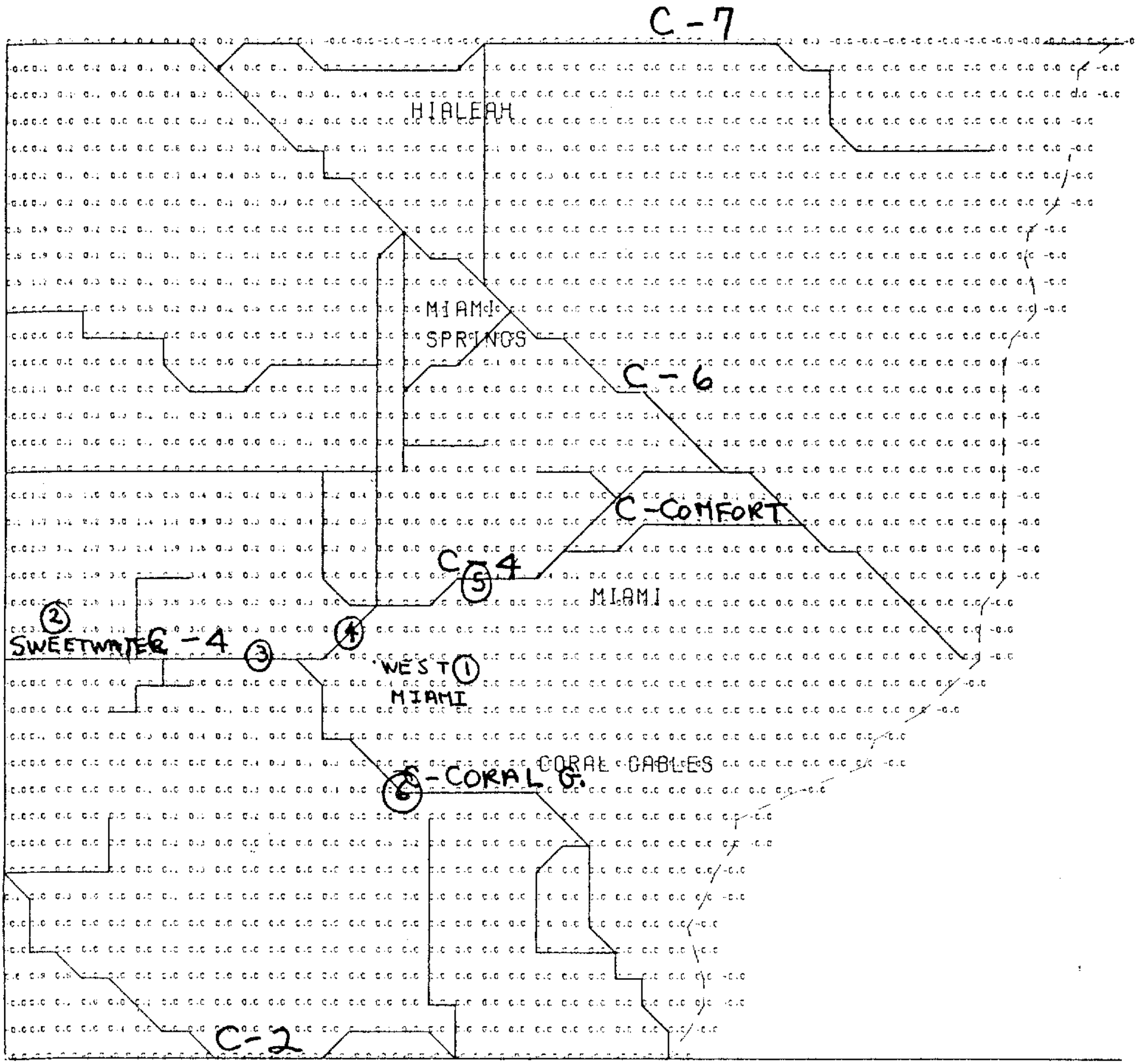
PONDING DEPTH.IN FEET*10 FOR END OF APRIL 24 1982 - secondary structure at C-4 & C-Snapper Cree (Alternative 2)

Figure 4C-4



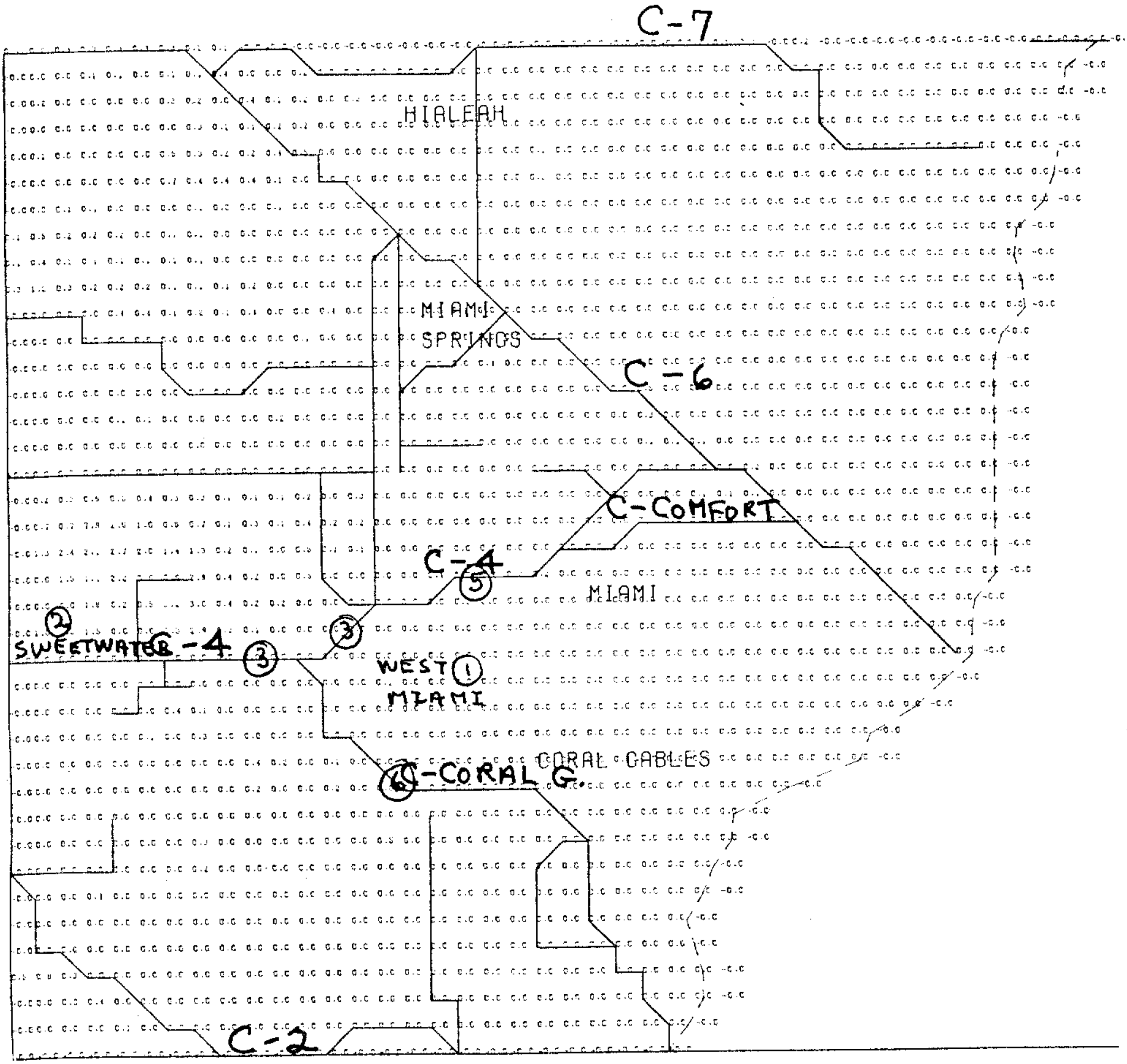
PONDING DEPTH, IN FEET*10 FOR END OF APRIL 25 1982 - secondary structure at C-4 & C-Snapper Creek
(Alternative 2)

Figure 4C-5



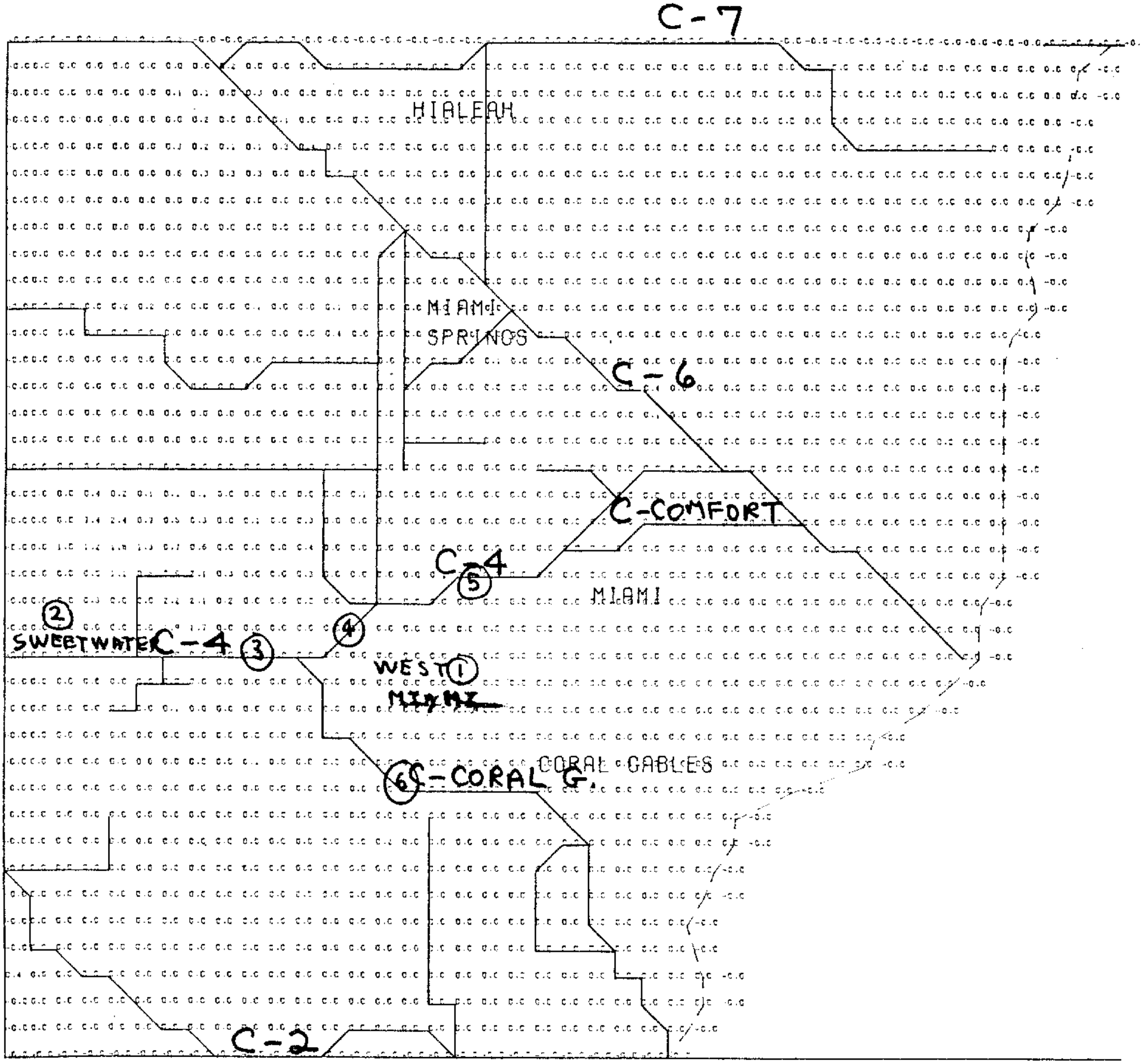
PONDING DEPTH, IN FEET*10 FOR END OF APRIL 26 1982 - secondary structure at C-4 & C-Snapper Creek (Alternative 2)

Figure 4C-6



PONDING DEPTH, IN FEET*10 FOR END OF APRIL 27 1982 - secondary structure at C-4 & C-Snapper Creek
(Alternative 2)

Figure 4C-7



PONDING DEPTH, IN FEET*10 FOR END OF APRIL 28 1982 - secondary structure at C-4 & C-Snapper Creek (Alternative 2)

Figure 4C-8